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VIEW OF FALKIRK AND THE FORTH VALLEY IN 1824.

Showing Carron Ironworks in distance. Drawn by I. Clark.

To face page 190.

THE STORY OF THE FORTH

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A FOSSIL TREE IN A CARBONIFEROUS LAVA STREAM.

Being inspected by the Author in 1910.

Frontispiece.

THE STORY OF THE FORTH

BY

H. M. CADELL

OF GRANGE, D.L.

B.SC., F.R.S.E., M.INST.M.E.

WITH 75 ILLUSTRATIONS
AND 8 MAPS

GLASGOW
JAMES MACLEHOSE AND SONS
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PREFACE

IT is more than thirty years since the author first began to collect the threads of material now woven into the following variegated fabric. During part of that considerable period he was professionally engaged on the staff of H.M. Geological Survey, where his attention was directed mainly to the scientific and physical aspects of the Forth Valley and the surrounding district. Since 1888 his life has been chiefly spent in promoting the industrial development and the public business of the part of the valley near his home in Linlithgowshire. His succession of diversified occupations has thus enabled him to look on the River Forth from more than one point of view—from the standpoint of the geologist seeking to penetrate into the mysteries of the remote past as well as from that of the industrial historian of more recent times, and the maker of local history in the present and the future.

Much of the matter now reproduced has already been published in the form of original papers, lectures and detached articles in various magazines, newspapers and transactions of scientific societies, both at home and abroad. At different times the author has been asked to republish some of these writings in a more readable and accessible form, and, indeed, other people have, in some cases, been kind enough to do this for him gratuitously. It is only lately, in the spare hours of a busy life, that he has found the necessary leisure to revise or rewrite some of these papers, and add to them a few new chapters from original investigations among statistical

records and old documents in his possession that have lain concealed for generations among musty bundles of family and business correspondence.

The geographical link is the principal connection of many of these chapters, and the first half of the book will probably appeal to a different circle of readers from those who may be interested in the second or industrial part.

This is not a political history, and the romantic tale of the fierce battles and bloody wars of which the Forth Valley was for centuries the theatre does not concern the record. The only kind of warfare mentioned in the narrative is the protracted struggle in the remote past between two competing rivers for the supremacy in Central Scotland, and in far later times the contest betwixt mind and matter, between civilised man and the unharnessed forces of wild nature. The subjugation and utilisation for the benefit of the human race of a primeval wilderness, the exploitation of its latent wealth, and the reclamation and betterment of the land and its people form the principal themes in the last chapters.

The book is thus not intended to be merely of local historic or philosophic interest to antiquarians and men of learning. It is also meant to be of practical use in some directions to the general community and to all who have the good of the rural parts of the land at heart.

The Forth Valley with its abundant natural wealth, and its profoundly interesting history of ancient events, including a record of the natural processes by which that wealth was accumulated in former geological times, is full also of future possibilities. Its long career of progress down the ages is by no means at an end. In a few years the Rosyth Naval Base, and possibly a Ship Canal at a later period, will greatly enhance the importance of the estuary and everything pertaining to it. The most important Scottish coalfields of the future are likely to be those of Fife, on the north side, while the seat of the great Mineral Oil Industry extends

along the southern shore, in the part of the Lothians to the west of Edinburgh.

An account is given of the development of some branches of Scottish national enterprise after the great awakening that began about 1760, including the establishment of Carron Company, the beginning of the modern Scottish Iron Industry, and in more recent times the rise and progress of the Mineral Oil Industry of the Lothians. From being a dismal wilderness, largely buried under morasses of peat, and peopled by a mere handful of poor inhabitants, the Forth Valley became, under the good generalship of a few patriotic and capable men, a highly prosperous part of the British Empire, with a large and busy population, in the end of the nineteenth century.

But now most of the large iron furnaces are extinct, and although coal and oil works are busy, territorial development in other directions shows signs of languishing, stagnation threatens to set in, and the best of the people and skilled artisans are following British capital abroad in search of better occupation. It is, therefore, high time for every patriotic Scot to wake up—and to such this book is addressed—and consider how best to put an end to this reaction, and resume such beneficent schemes as our enterprising ancestors started long ago. Although many of the local ironstone fields are exhausted, and the shallower coal seams are becoming worked out, there are still thousands of acres of reclaimable land capable of being turned to advantage in different ways, and made to provide remunerative employment to a far larger rural population.

The natural possibilities of the Forth are thus not nearly exhausted, and the author makes some practical suggestions as a contribution to the general discussion on one aspect of the great land question. He will feel well rewarded if any of his ideas prove of practical use in promoting the further development of the latent resources of the district and the betterment of its industrious people.

In conclusion, the author has to thank many good friends for their help in different directions. To Professor James Geikie he is indebted for the short and sufficient title of the book, and for other useful suggestions. Mr. A. H. Crichton and Mr. William Fraser have assisted in the account of the Oil Shale Industry, and Mr. David Ballingall in the account of the Blairdrummond Moss. The Royal Society of Edinburgh, the Scottish Society of Antiquaries, the Edinburgh Geological Society, the Royal Scottish Society of Arts, the Royal Scottish Geographical Society, Pumpherston Oil Company, and Carron Company have kindly given permission for the use of illustrations. To Dr. R. Kidston, F.R.S., he is indebted for illustrations of Carboniferous plants, and to Dr. J. Horne, F.R.S., and the Rev. A. Mitchell, M.A., for assistance in revision of the text.

GRANGE, LINLITHGOW,
January 1913.

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CHAPTER I.

THE FOUNDATIONS OF THE FORTH VALLEY.

THERE was a time in the remote ages of the past when Scotland as we now know it had no separate existence, and many millions of years were still to roll away ere our country began to assume its present form, and provide a cradle for the flowing rivers and a home for the Scottish people. The history of that far-off mysterious time is but dimly revealed in such fragmentary records as have been preserved in the rocky strata, and from these the geologist has been able to delineate only a few vague outlines of the ancient picture.

The Geological Record.—There is obviously great difficulty in deciphering with any degree of completeness the record of the rocks. These are made principally out of the sediments laid down in seas and estuaries, which have long since disappeared, and are mixed at a few places with beds of ashes and lava thrown out by the volcanoes of former times.

Let us try to imagine what kind of a picture the geologist of the remote future might be able to paint of our beautiful country merely from an examination of the debris of the land now being deposited in the adjacent sea. It had, let us suppose, like other prehistoric countries, been long ago washed away and rearranged, and its disintegrated materials had been all reconsolidated under the sea. Nothing remained except parts of the principal mountain ranges to tell what was the configuration of the lost territory. If these deposits, after long submergence, were upheaved and again

exposed to the light of day, our geologist might make some strange discoveries. Human bones might be found alongside of buttons, coins, and rusty streaks resembling chains and anchors crusted over with the fossilised remains of shellfish and barnacles. The bones of oxen and fishes, the hulls of submarines, and the skeletons of cargo boats containing a heterogeneous assemblage of coaly substances, machinery, and utensils, might all be found firmly embedded in a solid matrix of shale or sandstone. At other places there might be beds of rusty clinker, bricks, ashes, glass, and broken dishes, all more or less water-worn, mixed with sand and sorted out into a rudely stratified conglomerate, evidently an ancient littoral or shore deposit of some kind.

But these curious vestiges would not give him very much information about the lost Scotia. They could not indicate that there had been in the vicinity a picturesque hill called Arthur's Seat, overlooking a fair University city. All the perishable stuff, clothes, books, pictures, and papers would long ago have been reduced to humus, and any literary remains preserved in the fossil state would be principally confined to inscriptions on the more durable kinds of tombstones and surviving monumental tablets, describing the virtues, but none of the vices, of many individuals representing what had evidently been a singularly good and noble race!

All he could fairly conclude from such fragmentary data would be that there had been sea water in one place, and land somewhere else containing much iron and inhabited by civilised man, certain animals and several kinds of plants, with apparently very few birds, almost no insects, and that a fairly mild climate had been prevalent when they were alive.

In view of what is to follow it may be of interest to begin the story by devoting some pages to the history of the foundations of that part of the Forth Valley between Fife and the Lothians, in so far as it can be gleaned from the perusal of such imperfect records in the rocks as have been left for our investigation.

Old Red Sandstone.—The most ancient formation exposed in the district (with the exception of some patches of Silurian rock in the Pentland Hills) is the Old Red Sandstone, the materials of which had been washed away from some still older continent and deposited in great lakes inhabited by fish with hard, bony scales, and by curious crustaceans of enormous size. But the most important local episode of that period was the series of volcanic eruptions that threw out the beds of ashes and lava now to be seen outcropping in the Ochil and Pentland ranges. There were later volcanic outbursts in the Carboniferous period, but on a far smaller scale. The lavas of the Old Red Sandstone were poured out stream over stream until the volcanic plateau had accumulated to a thickness of about 6000 feet, and such a scene of fire and terror was never repeated in later ages in this district.

Carboniferous Period.—In time these primeval fires cooled down and the area subsided below the sea. The Carboniferous age, whose history is far more interesting and better known, succeeded the Old Red Sandstone period. Since the later industrial history of the Forth, which has much to do with the question of coal consumption, arises out of the earlier records of the period of coal production, some account of the latter deserves a place at the beginning of this narrative.

As the Old Red Sandstone rocks sank below the ocean they were gradually buried under beds of gravel, sand, mud, limestone, and marl, mainly derived from the waste of some older land-surface. The volcanic mountains of the previous age were the last parts of the Old Red land to disappear, and the Pentland ridge remained as an island above sea level, while the Lower Carboniferous strata were being deposited in the adjacent waters. These beds, known geologically as the Calciferous Sandstone series or Lower Carboniferous division of the formation, measuring from the top of the Old Red Sandstone and including the Oil Shale group of strata, have in the Edinburgh district an aggregate thickness of about 5500 feet.

We find here among other rocks the thick beds of sandstone of Craigleith, Granton, and Hailes, out of which most of the New Town of Edinburgh was built more than half a century ago. The old lavas on the east side of Arthur's Seat belong to this period also, showing that volcanic activity was not yet quite extinct in what is now the East of Scotland. Forty miles to the west, however, there might be seen in the far distance a chain of volcanic peaks belching out black clouds of smoke and fiery floods of lava from many vents on the line of the Campsie, Kilpatrick, and Renfrew Hills. These Western volcanoes remained active long after the original lavas of Arthur's Seat had cooled down and disappeared under the rising sea, and indeed they remained unsubmerged during the whole of the important period we now arrive at in which the oil shales of the Lothians were being produced.

Oil Shale Period.[1]—The most interesting part of the Lower Carboniferous period is that in which were produced the seams of oil shale that afterwards became of great economic value in the Lothians, and gave rise to the important local industry described in another chapter.

The physical conditions favourable to the production of oil shale were, strange to say, confined almost entirely to one particular district, and although strata of the same age are to be found spreading over a far larger tract of country they do not include oil shale seams of any consequence outside of this special area. It is further a remarkable circumstance that these peculiar conditions continued to prevail inside the charmed circle for a long geological period. We find not merely one shale seam, but a whole succession of oil shale deposits separated by other kinds of rock, and extending downwards through a total thickness of strata of about 4,000 feet. There are seven perfectly distinct seams or groups of seams of workable oil

[1] Vide *The Oilshales of the Lothians.* Part I. The Geology of the Oilshalefields. By H. M. Cadell, B.Sc., F.R.S.E., and J. S. Grant Wilson (*Memoirs of the Geological Survey*, 1906, pp. 1-97); also the *Survey Memoir on the Neighbourhood of Edinburgh*, 1910, pp. 75-103.

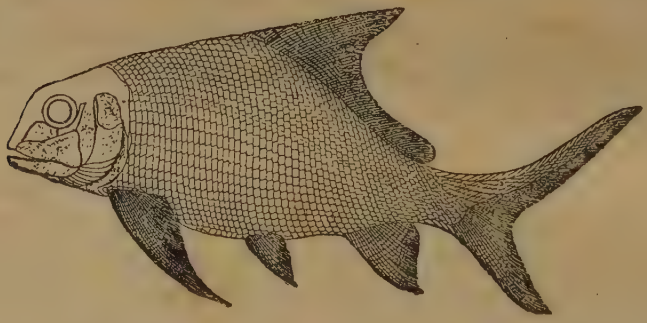
shale varying in thickness from 2 up to 90 feet, but though most of them have been proved by mining operations to extend over a good many square miles, the whole of them never occur in a workable condition in any one place. The positions of the shale seams and other rocks of the local Carboniferous system are exhibited in order on the section, at the end of this chapter, which includes a total thickness of 9,000 feet of strata.

We are now discussing the subject principally from the historical point of view, and considering it in connection with the gradual development of the physical geography of the Forth Valley. We may first consider the kind of place and climate that existed in this part of the world when the oil shales were being produced.

Origin of Oil Shale.—From the abundant fossil remains that are found in the shales it is evident that the climate of the period was mild enough for plants and animals to thrive and multiply both on land and in the water. The oil shales have been originally beds of fine mud mixed with plant and animal remains. The organic matter, for the most part reduced to an impalpable state, has been precipitated to the bottom along with the fine inorganic clay suspended in the water. The shale as it comes from the mine in its natural condition is fairly homogeneous in texture, but after being distilled for oil and heated to redness in the retorts and then thrown out on the refuse heap as "spent shale," it is seen to be made up of extremely fine laminae, sometimes almost as thin as the leaves of a book, which are not apparent in the original rock. This minute lamination is not generally to be found in ordinary *blaes* or clay shale, which even after being calcined remains a more or less solid mass in thick or thin beds with a brick-like texture and only coarse lamination here and there.

I have had many opportunities of observing the character of the mud of the Firth of Forth which, when slowly deposited at sheltered places on the shallower parts of the foreshore, is found to be well laminated, in leaves perhaps $\frac{1}{8}$ inch or less in thickness. Each of

these laminae represents the deposit of a single tide, and if the water were to be always more or less muddy and the process were to go on regularly and unintermittently for a year we ought to find an annual deposit of about 700 laminae, corresponding roughly to the number of tides covering the shore in that period. The laminae show that there has been a rhythmical and constant, if small, interruption in the process of deposition, perhaps only of a day or half a day. The interruption was, however, sufficiently long to have broken the perfect continuity of the deposit and to have distinguished it from a homogeneous bed of clay such as might be thrown down in

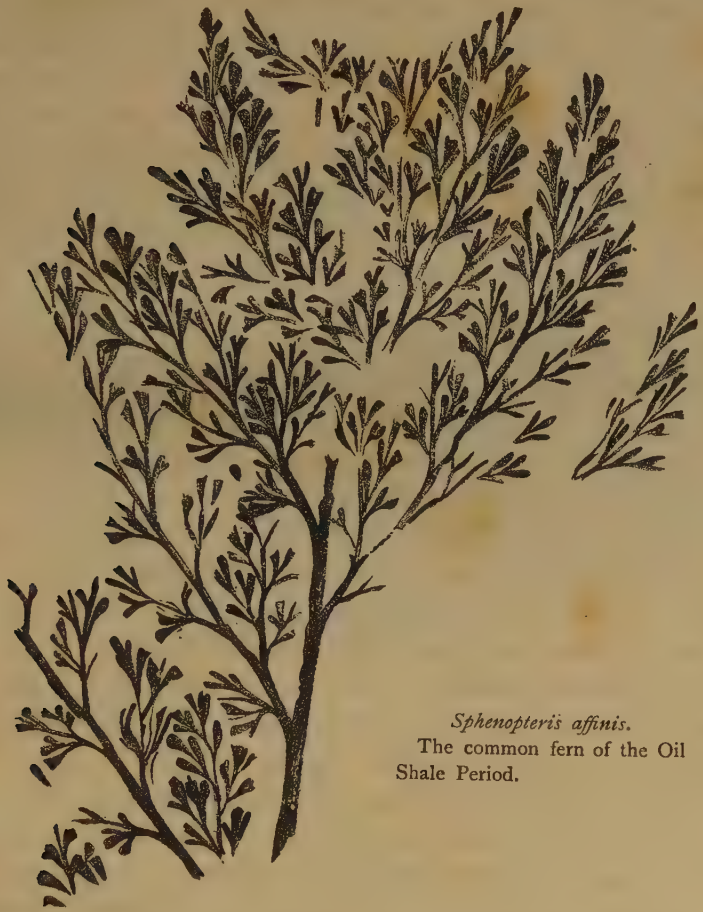


Elonichthys crenatus (after Traquair). A common fish of the Oil Shale Period.

a lake or at the mouth of a muddy river where there was no intermission to the precipitation of silt. The water must, during these shale-producing periods, have been free from strong currents. These would have had the effect of washing away the fine sediment and the light organic ooze, and also of mixing the mud with coarse enough material to destroy its distinctive character as an oil shale.

The subject, like the much-debated question of the origin of coal, is not free from difficulty. It may, however, be said with certainty that oil shale differs in origin from most kinds of coal in being an undoubted aqueous deposit or precipitate composed generally of 70 to 75 per cent. of ash, originally inorganic mud, with 30 to 25 per cent. of organic matter, partly animal and partly vegetable in origin, from

which the valuable hydrocarbons and ammonia are obtained. There are, however, cases, such as that of the famous Torbanehill or Boghead mineral, where it has been found extremely difficult to distinguish between some kinds of oil shale and some varieties of cannel coal.

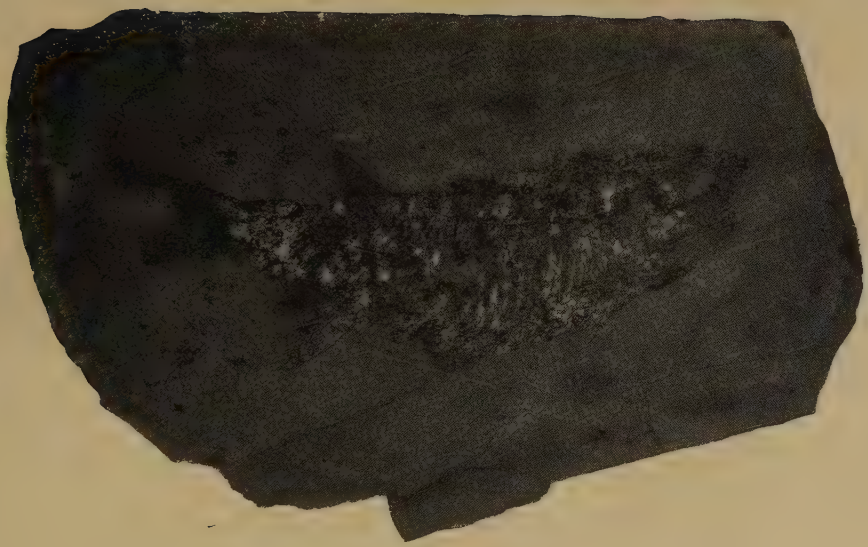


Sphenopteris affinis.
The common fern of the Oil Shale Period.

My view is that in the case of the oil shales the area in which they were produced was always submerged under an expanse of more or less shallow water inhabited by various kinds of fish, crustacea, and small aquatic animals. There were one or more wide lagoons

near rivers flowing off an ancient continent which was probably covered with peaty vegetation whose macerated debris was washed off by the rain and carried away by sluggish currents. In the same way black impalpable vegetable ooze is swept from peat mosses into quiet pools at the present day, and deposited along with the ordinary mud in the sluggish or stagnant water, which may be more or less turbid according to the weather and amount of rainfall. In some of the oil shale seams, particularly those situated near the bottom of the series, and mined at Pumpherston, several kinds of fossil fishes are very common, while other shale seams are almost entirely composed of minute entomostraca or cyprids, small crustaceans with bean-shaped shells that give the shale the appearance of a fine kind of linseed cake. In addition to these animal remains, fronds of ferns and other plant remains are often to be seen, which perhaps represent only a few of the most durable of a large variety of vegetable substances floated from the nearest land. The commonest of the ferns was the *Sphenopteris affinis*, of which the figure on the previous page is a drawing by Dr. R. Kidston, F.R.S.

The Oil Shale Lagoon.—The lagoon in which the shales were formed must have been an extensive sheet of water, at least 20 miles in diameter, and perhaps 30 or 40, as we do not know accurately how much further east and west the seams extend under the newer strata of the Coal Measures. Over such a large area it is not to be supposed that there was, in all places, perfect regularity in the deposit of silt, as in some places the quantity of organic matter in the shales is found to be greater than in others. But it is surprising to find evidence of such a well-marked seam as the Dunnet shale having been deposited apparently in a fairly continuous state, over an area extending for 22 miles from Cobbinshaw on the south to Burntisland on the north, and for 15 miles from Straiton on the east to Philpstoun on the west. These figures show the lagoon to have had a surface of 330 square miles, and probably we should find this was originally much more if we could discover the additional extent of



MESOPOMA MACROCEPHALUM. (Natural size.)

A common fossil fish in the Pumpherston Shale.

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the deeply-buried parts under the Mid and West Lothian coal-fields. The area of the shalefields is shown on the map at p. 36.

These submerged mud-flats, no doubt near to or connected with a great estuary, may have been subject to daily or periodical floods from the river, or there may have been tides in the sea outside which affected the flux and efflux of the fresh water currents in the lagoon. At low tide there would naturally be an outflow, but this would cease and the impounded water would flow back or become stagnant when the tide was rising, and during this stationary interval at slack-water we may well imagine that a layer of silt would continue to settle until the water gradually began to move outwards when the tide fell below a certain level. We should thus have a deposit of laminated mud like that which is formed at slack-water in sheltered enclosed tidal basins on the modern foreshores of the Forth.

These calm intervals, however, were subject to rude interruptions. The whole ground was subsiding as the sediment accumulated on it, and sometimes the currents ceased to be languid, and more powerful streams swept over the lagoon and covered up the shaley ooze with thick beds of sand and ordinary mud, without much organic matter in it. That large trees as well as tender ferns grew on the vanished land of the period is proved from the fact that seeds and branches of the lycopodiaceous trees of the time are to be found embedded in the strata between the shale seams, while there is evidence that the nearest land was covered with coniferous forests.

The Craigleith Fossil Tree.—The stem of a great conifer was found embedded in the Craigleith sandstone in 1826, pieces of which can still be seen preserved at the Royal Botanic Gardens in Edinburgh and on the terrace of the Royal Scottish Museum. Two still larger stems—the largest fossils ever found in Scotland—were afterwards revealed in the same geological position in the sandstone at Granton. One of these is stated by Hugh Miller to have been 4 feet in diameter and 70 feet long. The other was 6 feet in diameter at the base and 2 feet at the top. It was only a fragment of a tree

that may have been originally 100 feet high.[1] The Craigleith stem was 47 feet long when discovered and slightly flattened, the diameter at the base being 5 feet by 2 feet.[2] Before it began to attract the attention of geologists a good many feet had been broken off the point, and had it been all preserved the trunk might well have been that of a noble tree 60 ft. or more in height.

This, however, is an old story told in many text-books, and my only object in referring to it is to draw attention to a point which has, perhaps, not been noted before. I refer to the question of the time these sandstone beds took to form. The accompanying picture taken from Mr. Witham's description shows that unlike most fossils the stem was not lying flat on the bedding planes of the rock, but was inclined to them at a considerable angle. The rock was dipping in one direction at an angle of 20° and the stem was sloping in another direction, so as to make an angle of about 45° with the inclination of the strata. This shows that the tree was sticking in the sand at half a right angle until it was entirely buried up. It must be remembered that it had a good skin of bark which was fossilised into coal like the lycopod bark of the Coal Measures, but the central core of the wood remained intact and became petrified in time, so that the internal structure and rings of growth could be clearly seen. In fact the tree had not time to rot like one of the lepidodendra of the Coal Measures, but was entirely buried up in a very few years by the quickly rising sand. In similar circumstances a pine tree sticking in the bottom of a current of running water in our time would soon break off. It would rot away, be eaten by insects, or at least have its bark entirely destroyed in less than fifteen or at most twenty years, as harbour authorities who have wooden piles to maintain know to their cost. Thus, I think, we may safely assume that the Craigleith tree could not have been so well preserved

[1] *Edinburgh and Neighbourhood*, 1864 ed. p. 73.

[2] Minutely described by Mr. H. Witham in the *Transactions of the Royal Society of Edinburgh* (Vol. XII. 1832, pp. 147-152).

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THE CRAIGLEITH FOSSIL TREE.

unless it had been buried up in twenty years' time at most. If it was originally 60 feet long and lying at an angle of 45°, the depth of the bed of sand required to bury it would be 42½ feet, or, in other words, the sand silted up at the rate of more than 2 feet per annum, and probably considerably faster than this. The two pictures in Mr. Witham's paper, which appear to have been accurately enough drawn, the larger of which is reproduced here, show about nine separate beds in the part of the rock surrounding the fossil, and we may thus quite well conclude that each bed represents no more than the accumulation of a single season, and perhaps even of a shorter time than this.

Burdiehouse Limestone.—For a time there was a complete physical change in the circumstances of the period. The water, still fresh, or perhaps only brackish, became comparatively clear. It was inhabited by numerous fishes and other organisms, chiefly ostracod crustaceans, whose calcareous shells were deposited in myriads along with a small quantity of floating vegetation, but almost no mud. This in time produced a bed of solid limestone, at places 30 feet in thickness. The Burdiehouse or Camps limestone is a well-known fossiliferous stratum in Mid and West Lothian and at Burntisland in Fife, and has been largely quarried for ironworks, building, and agricultural uses. It extends over practically the same area as that of the oil shales, and is at times covered by a seam of workable oil shale, showing a return of the former physical conditions.

Houston Coal.—Such conditions prevailed for a long period during which the Dunnet shale, Binny sandstone, Broxburn and Fells shales were formed in succession. But after the last of these strata had been deposited, a seam of coal—the oldest in Scotland—made its appearance. The Houston coal is a true coal bed, but a very impure one, containing a great deal of ash, which makes it hardly workable nowadays, except perhaps during a coal famine—such as unhappily occurs now and then, when almost anything black acquires a temporary fuel value. This bed of coal points to a change in affairs and the beginning of a new chapter in the record. The old lagoon

became shallower, or perhaps a slight upheaval took place which permitted vegetation to accumulate and prevail over the mud-flats, just as great peat mosses accumulated long afterwards on the uplifted Carse lands of the Forth, to be described in a subsequent chapter.

Houston Marl.—A far more remarkable event now took place that brought swift and terrible destruction on every living thing in the region. A short distance above the coal seam there is a thin seam of oil shale, full of the bean-shaped shells of minute cyprids (or entomostraca), and this is covered by a deposit of a peculiar and very fine-grained rock that lies in massive amorphous beds separated by thin ribs of hard stone. Partly greenish and partly reddish in tint, it is known to mining men and geologists as the *Houston Marl.* This stratum extends over nearly all the shalefields and is in places more than 200 feet in thickness. It indicates a complete change in the geological sequence of events, and has never been found to contain any traces of fossils. The rock is not really a true marl, which is a mixture of clay and lime, but has been so designated by miners for want of a better name. Its origin is mysterious, as it is distinct from almost every other kind of rock in the district, and is neither a clay bed nor a limestone, although it contains both clay and lime. It is at places mixed with pieces of true volcanic ash, and as we trace it over to Fife we find it to be represented by thick beds of basaltic lava in the Burntisland district. These volcanic rocks form a great bank just above the Houston coal and round the Binn Hill.

A Great Volcanic Eruption.—The bulk of the evidence leads us to believe that the marl is in fact the decomposed representative of a vast shower or succession of showers of fine volcanic ash thrown out of one or more volcanoes which burst forth and devastated the whole region. There may have been different craters or vents, but one of them was undoubtedly the Binn of Burntisland, which is an excellent example of a dissected Carboniferous volcano. Lava streams spouted up or welled forth, spread over the immediate vicinity, and consolidated into beds of whinstone. But by far the

greatest effect of the eruption was the enormous cloud of ashes and dust which was thrown high into the air, and after being wafted hither and thither by the wind and wet by the rains, settled down on land and water in a deadly pall of fine volcanic mud, smothering the face of nature over hundreds of square miles. The great extent and thickness of the deposit—some 230 feet in the West Calder district, 20 miles away from the Binn—leads one to think that there must have been another vent, or several of them, situated to the west, the position of which is probably concealed under the more recent volcanic lavas of the Bathgate Hills. But however that may be, it is certain that volcanic activity, after a long period of rest, burst forth again and rudely disturbed the placid face of nature in the latter end of the Oil Shale period.[1]

The marl always forms one single stratum, of different degrees of texture no doubt, but undivided by beds of shale or thick sandstone, and this shows that, while the conditions lasted, the process by which it was produced went on without cessation. There is no lamination or fine bedding in the rock, and there must thus have been a continuous shower, or more likely a succession of showers of fine dust which settled into amorphous beds of muddy looking rock with only a few hard ribs of stone between them.

The widespread volcanic action—if volcanic action it was—which produced the marl ceased as suddenly as it began. The blight was at last removed and life began to teem in the region once more. A few feet above the marl we find a second but very thin seam known as the Two-feet coal, which shows that vegetation was waiting to spring into life again whenever the physical conditions permitted.

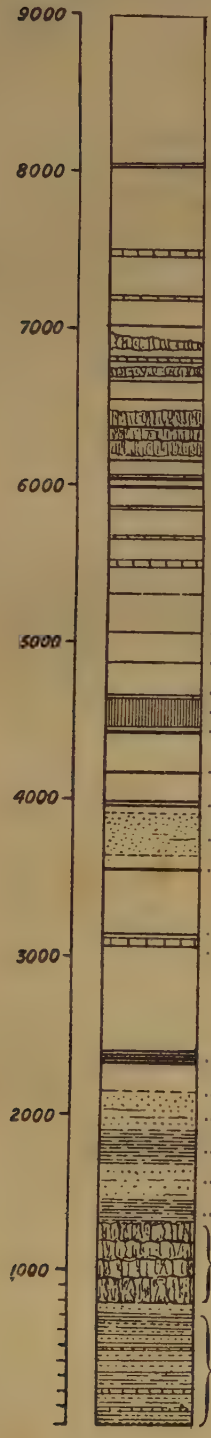
There was, however, still some volcanic activity in the district. The Two-feet coal is covered by a thick bed of volcanic ash in the

[1] The sudden explosion of Mount Tarawera in New Zealand in June, 1886, which in a few hours destroyed the famous Pink Terraces and smothered a wide district under a bed of fine ash without any lava, which under the influence of the weather became partly converted into mud, was a modern example on a small scale of such an eruption. *Vide* "A Visit to Mount Tarawera," H. M. Cadell, *Scot. Geograph. Mag.* 1897, pp. 246-259.

neighbourhood of Uphall, but this is more or less of a local deposit, and the ash did not devastate a wide area. A few less important oil shale beds were afterwards produced, but the lagoon was now disappearing for ever, and the whole region was beginning to settle down under the briny ocean, whose deep, clear waters crept in, covered the mud-flats, and put an end for a time to the formation of any more oil shale.[1]

[1] The generalised section on the opposite page shows the Hailes, Craigleith, and Granton Sandstones and the Wardie Shales as included in the Oil Shale group. This is the classification adopted recently by the Geological Survey, on the ground that thin seams of true oil shale have been discovered so far down in the series. But hitherto no workable seams of shale have been found at such a distance below the Pumpherston position, and in the appended sketch map of the shale fields, I have, from the point of view of the practical miner, only included in the oil shale area the part of the ground that may be reasonably expected to yield seams of shale that can be profitably worked. This is the explanation of the apparent discrepancy between the diagrams.

GENERALISED VERTICAL SECTION OF THE CARBONIFEROUS SYSTEM IN MIDLOTHIAN AND WEST LOTHIAN.



Upper Red Sandstones devoid of coal

Coal seams of Dalkeith, upper Coals of Alloa, Stirlingshire and Fife

Thick-ness. Feet.

COAL MEASURES...1000

...Slateyband Ironstone and Boghead position

Coarse Sandstones, Grits and Fireclays

MILLSTONE GRIT... 500

...Castlecary or Levenseat Limestone

...Calmy or Arden Limestone

Thin Coal Seams and Volcanic Beds

...Index Limestone

Coal Seams, Ironstones and Volcanic Rocks of Bo'ness and Bathgate, also Edge Coals of Midlothian and chief coalfields in West of Fife

CARBONIFEROUS LIMESTONE SERIES.....2000

...Hurlet or Gilmerton Limestone

...Black Band Ironstone

...Raeburn Shale

...Mungle Shale

...Two-feet Coal

...Houston Marl

...Houston Coal

...Fells Shale

...Broxburn Shale

...Binny Sandstone

...Dunnet Shale

OIL SHALE GROUP, 4000 ft.

...Camps Shale

...Burdiehouse or Camps Limestone

LOWER CARBONIFEROUS OR CALCIFEROUS SANDSTONE SERIES.....5500

...Pumpherston Shales

...Thin Oil Shale

...Hailes Sandstone

...Wardie Shales, Thin Oil Shale

...Craigleith and Granton Sandstone

...Abbeyhill Shales

Volcanic Rocks of Arthur's Seat and Corston Hill

CEMENT STONE GROUP, 1500 ft.

Ballagan Beds=Marls Cement Stones, Red Shales and Sandstones resting on the Upper Old Red Sandstone

Total thickness, 9000 ft.

CHAPTER II.

THE AGE OF SWAMPS AND FORESTS.

Carboniferous Limestone Period.—The ocean which now crept over the scene was far shallower here than in the southern part of the British area, and indeed there were times when the sea disappeared altogether and left the low-lying ground quite bare. The existence of thick beds of limestone made up of corals and marine shells shows that the water was deep and free from mud or floating vegetation. But in Scotland this state of matters was only temporary. The great Mountain Limestone, thousands of feet thick in England and Ireland, is here split up into half-a-dozen beds, none of which are more than 50 feet thick. Between these there are beds of sandstone, blaes (the Scots name for *carbonaceous* as opposed to *oil* shale), fireclay, ironstone and coal, which occupy by far the greater part of the section. These were produced near the shore while the southern area was entirely hidden under the deep blue sea. There were probably some islands of the older Silurian rocks of the Southern Uplands which were not covered by the sea. The mainland lay somewhere to the north and west where the crystalline rocks and Highland schists and slates formed an old shore line to the Carboniferous ocean.

There must have been a large continent to be washed away somewhere in the neighbourhood, otherwise there would be no sediment to produce new rocks in the sea bed. The Forth district was evidently on the border of that lost continent whose fringe of

detritus must have extended seawards for many miles, and was in time entirely covered up with sand and mud. It was later on converted into a vast swamp or delta clothed with dense vegetation, through which, no doubt, the mouths or "distributaries" of some great river meandered sluggishly outwards to the distant sea.

The Coal Age.—This was the beginning of the true Coal age. In Scotland the lower division of the coal-bearing rocks contains several marine limestone beds and some fossiliferous shales containing marine shells. These show that the sea was never far away at this period, and from time to time broke in and made incursions into the swampy estuary, covering the sinking ground with coral reefs and the shells of marine organisms.

While the surface of what is now England and Ireland lay sleeping in the bed of the sea under water that produced nothing but solid limestone, Scotland was better employed in laying the foundation of future prosperity by manufacturing valuable seams of coal and ironstone in the ancient estuary. The upper or true Coal Measures of England and Scotland which contain the thickest seams, were produced at a later time, but the coal seams of the Limestone or lower Coal Measures, although of smaller dimensions, are yet of extreme importance to the industry of Fife and the Lothians.

Origin of Coal.—The question of the origin of coal is always one of deep interest, and it has led to endless speculation in the past. Indeed the discussion still goes on spasmodically as new light is thrown on the problem by observers in different countries. Everyone agrees, no doubt, that coal is fossil vegetation of some kind, but whether it was formed in the light of day on dry land by the decay of great forests, steeped in inland swamps like peat, or drowned in sea water full of plant remains, first afloat and then submerged, is a question to which I believe no one answer will ever be given. That coal has been formed in more ways than one admits of no doubt. Carbon occurs in the rocks in several forms. Beginning with graphite or pure carbon in the shape of diamonds, it passes upwards through anthracite, bituminous

coal, brown coal or lignite to the black peat being produced in the lower parts of mosses which are still covered with growing vegetation.

Brown Coal.—Brown coal or lignite is scarcely known in Scotland, but it occurs abundantly in different parts of Germany. It is made from wood that has been washed into lakes or pools in large quantities where it has become waterlogged and has sunk and been covered up by alluvial deposits during the Tertiary period. Brown coal seams are lenticular in shape, and are sometimes more than 150 feet thick in Germany. Although the woody structure is quite visible, the whole has been solidified into one homogeneous dry peaty mass, but much more fossilised and brittle than ordinary peat.

The German brown coal is composed principally of two species of wood, and is not made up of bark like most of the black Carboniferous coal. It has been proved experimentally that coniferous wood can be changed into brown coal by long continued heat and pressure. In the Oberbergamts Museum at Clausthal in the Harz Mountains I remember to have seen in 1882 a specimen of a substance which was indistinguishable from the true Tertiary brown coal mined in the vicinity.[1]

This came out of the Dorothea Mine, one of the ancient copper and lead mines at Clausthal, where an old level had been reopened some years previously after having been sealed up for about 400 years. The heat of the slowly fermenting massive pine timbering, the absence of air, and the high temperature of the decomposing pyrites occurring in some of these ancient workings, in conjunction with the great pressure of the superincumbent hanging wall of the vein, had hastened what would otherwise have been a slow geological process, and had metamorphosed the imprisoned wood into a solid mass of excellent lignite. Had the process been continued for some thousands of years longer the metamorphism might possibly have converted the brown into black coal something like that of the Carboniferous formation.

[1] *Vide* H. M. Cadell, "The Geology of the Harz Mountains," *Proc. Roy. Phys. Soc. Edin.* Vol. VIII. 1884, p. 229.

Scottish Coal.—In Scotland there is very little anthracite, and we have generally to consider only two distinct kinds of coal, both of them more or less bituminous in character:

1. Common or rough coal.
2. Cannel or parrot coal.

1. This is the ordinary house coal used mainly for domestic and steam-raising purposes, and is known to blacken objects which touch it. Most kinds of house coal when examined are found to be laminated in texture with clean lustrous layers separated by thin partings or laminae of a sooty kind of natural charcoal, or "mother of coal," which soils the fingers when touched. In good kinds of coal fossil plants are not as a rule to be found in the heart of the seam itself, but the flattened stems of lepidodendroid trees, calamites, etc., are common in the shale or sandstone which forms the roof of the working. In some cases there are in the coal-seams large knots of ironstone like stools of trees passing up into cylindrical stems which penetrate the roof of the seam for a foot or two. These mineralised knots are surrounded by a cylindrical pipe or skin of true coal, which may be a quarter of or half an inch in thickness. They are known to the miners as "pot bottoms," and are not favourites, as they are apt to drop out of the roof and cause accidents.

A Fossil Forest.—I have more than once explored an old forest of this kind at Bridgeness, in the submarine workings of the Craw coal, a thin seam of common coal above the ironstone and parrot coal, which has not been worked for many years, but was open in 1879 and 1881. I counted on one occasion no less than 113 old stumps, whose fluted bark showed them to be principally of the genus *sigillaria*. These were distributed at intervals along a distance of 400 yards of roadway, and the space between each tree must therefore have been on the average about 10½ feet. If this was the average for the whole wood, there must have been 395 trees growing on every acre, which implies a forest of very great density. They were not at regular

distances, but were in clumps. The stems were of various sizes from 2½ inches to 2½ feet in diameter, the average being about a foot, with a ring of coal ¼ inch thick round each stem. A considerable number were leaning over to the north or lying almost flat, so that the length could be partially measured in the roof of the seam. The longest I noticed was a flattened stem 1 foot wide, lying prostrate and exposed for a length of 6 feet. The thickness of this seam was only about a foot, and the trees were all found on the top of it, and not extending down into the coal itself. The Six-feet seam, a few fathoms deeper down, contains large ironstone balls such as I have mentioned. These are connected with stems which rise upwards a short distance through the roof. The fact that many of the stems in this primeval forest were lying over to the north would indicate that the prevailing wind was from the south, or that the whole wood had been affected by a southerly gale.[1]

Here we have perfectly clear evidence that the coal was formed *in situ*, and its vegetable constituents had not been transported from a distance. How could a standing forest of thick trees be moved about like the famous Birnam wood in Macbeth's days? Moreover, the fact that the seam is only a foot thick, and that the trees were growing on the top of it, shows that they had little hold of the ground. The fact that they were not overturned goes to prove that there were few storms or strong winds prevailing at that period. Winds are the enemies to luxuriant forest growth, and we must therefore conclude that the air was sluggish like the waters, and storms did not often disturb the monotonous life of the coal swamps.

The only coal belonging to the stems was the pipe of fossil bark in which each was encased. The woody fibre inside had all decayed into touchwood and had been replaced by ironstone or sedimentary matter. Hence we conclude that these trees rotted away inside like the birch of our own times, and that the bulk of the

[1] *Vide* H. M. Cadell, "The Fossiliferous Rocks of Bo'ness Coalfield," *Trans. Edin. Geol. Society*, Vol. IV. 1883, p. 325.

LEPIDODENDRON VELTHEIMIANUM.

SIGILLARIA MAMILLARIS.

Impressions of Bark of two common Carboniferous Trees.

To face page 20.

timber disappeared, leaving only the bituminous or resinous bark standing in the form of hollow cases or skeletons when they died. These in time fell over and collapsed, and the fragments of rotten touchwood inside became mineralised into sooty mother of coal, while the hard lustrous layers represent no more than the original skin of bark. Those hollow stumps which remained standing for a while after the conditions had changed and after the forest was finally submerged became filled up with ferruginous mud that turned into ironstone in time. When the bark could no longer bear the strain it broke off, leaving the whole to be levelled over by the rising sediment.

Ancient Soils.—Underneath some, but by no means all, seams of this kind of coal there are traces of an ancient soil, either fireclay, sandy shale, or sandstone, containing stigmaria roots and thin rootlets radiating from them. These show that there was once something solid on which trees could grow. But such root-infested strata are often found without any coal seams upon them at all, which shows that the vegetation often rotted down or was all washed away without leaving any further traces of its existence, and it was only in special circumstances that the remains accumulated so as to form beds of coal. If the soil was so wet and swampy that oxidation was retarded, the decomposition would be arrested, as in peat mosses. The kind of vegetation had, however, no doubt much to do with the preservation of the substance, as there might well be trees at that time, as there are now, whose bark rotted as fast as the interior, leaving nothing behind capable of becoming fossilised.

2. *Cannel Coal.*—The other kind of coal, principally of value as a producer of good gas, had a somewhat different origin. Cannel coal is apparently a true shallow water deposit. It is a clean, more or less glossy, homogeneous substance, with no sooty layers in it, and breaks with what is known to geologists as a conchoidal fracture. In other words, a chip of it has more or less the shape of a flat curved shell. It frequently contains scales, teeth, and the bones and skins of whole fish. These fish lived in the water where the coal was

deposited, like the oil shale fishes we have already noticed. As will be apparent from the accompanying photograph, these fossil teeth, the only part of the animal that has been preserved, are at times from 3 to 5 inches long. They show that the pools were dangerous places, with ferocious monsters inhabiting them. The rhizodus, which had the largest tusks, was a carnivorous fish which subsisted on smaller fry, and there must have been enough of animal food to provide grist for his hideous jaws. Footprints of land animals have also been recorded by Hugh Miller in the Dalkeith coalfield.[1] Scorpions and huge spiders were there also, and they must have had smaller creatures to sting and prey on. If the geological record is to be trusted, the country was not a very desirable place for residence at that time.

The vegetation, however, was not precipitated to the bottom and mixed with a large quantity of sediment. It was, I believe, often held more or less in suspension in a shapeless pulpy state, like a floating morass, such as the dismal swamps of Virginia or the sudd of the Upper Nile. Vegetation of some kind must have been growing on it, as it is common to find flattened stigmaria roots often converted into iron pyrites, with rows of short, dumpy rootlets springing outwards from them. These were shaped like candle flames, and evidently of a different species from the long, wavy, ribbon-like forms which occur in the fireclays and old soils already referred to.

Ironstone.—In many of our bogs, swamps, and shallow fresh-water lakes, it is common to find a spongy deposit of rusty brown ironstone or "pan." Sometimes this has been found to occur in sufficient quantity to be workable for iron smelting. Indeed, a great deal of the famous Swedish iron of the eighteenth century was made from bog ironstone fished in lumps from shallow lakes in that country,

[1] These footprints were discovered by the late Mr. Henry Cadell, the writer's father, while he was in charge of the Duke of Buccleuch's collieries in 1853, and Hugh Miller describes his visit in *Edinburgh and Neighbourhood*, 1864 ed. p. 73.

TOOTH OF *RHIZODUS HIBBERTI*. (Natural size.)

Ironstone Seam, Grange Colliery, Bo'ness.

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where it regularly accumulated and could be ingathered like a crop at intervals of several years. The iron in solution as carbonate, in some kinds of water, is oxidised and precipitated by the chemical action of the air and the growing vegetation, and the rusty powder may become mixed with ordinary mud and vegetable or animal remains as it sinks to the bottom. In course of time this ferruginous mud, after long exposure to the carbonic acid which has been produced by the decomposition of the organic substances, may be reconverted into carbonate of iron. Thus it comes about that beds of ironstone are often associated with coal seams, particularly of the cannel variety. Ironstone does not occur between beds of sandstone or limestone as a rule. It is generally found in thin beds or nodules in clay shale not necessarily associated with coal seams at all, and always in places where there has been mud containing organic remains in greater or smaller quantity. A small shell, leaf, or fragment of a fish, or indeed a whole fish skeleton, is generally to be found in the centre, if we split open an ironstone nodule in a bed of clay shale. The organic particle has attracted in some way all the iron in the mud for some distance round, and this has, when mixed with clay, become in time converted into what is known to miners as *clay band ironstone*. If there has been little or no clay, but much vegetable or peaty matter in suspension to mix with the ferruginous precipitate, it has produced a bed of so-called *black band ironstone*—a class of ore of great value to Scottish ironmakers.

The blackband ironstone, once abundant in some parts of the Forth district, is now unhappily nearly all worked out, as the deposits in the Carboniferous lakes and swamps which produced it have almost all been exhausted by the miner. Unlike modern bog ironstone it will never grow again. The coaly matter which it contained enabled it to be easily calcined without the addition of fuel, such as must be mixed with clay band ironstone in the first metallurgical process preliminary to the final smelting in the blast furnace. Such ironstone beds are seldom much over a foot, and may be as little as

an inch or two in thickness, and as a rule they are knotty and irregular, as might be expected. They occur in isolated areas or detached basins, and do not, like the thicker coal seams, extend over large districts. They often thin out, and are found to pass into beds of cannel or ordinary coal as we trace the strata from one place to another. They are often full of excellent fossils. Sometimes these are a species of fresh-water mussels or the scales, spines or teeth of gigantic fish, or the beautiful bark of a Coal Measure tree or reed which has sunk in the red mud and left a sharp impression on the fine matrix while it was still in a soft and plastic condition.

It is a curious fact that no ironstone beds exist among the oil shale strata. These begin to appear at the very top of the oil shale series and occur at intervals throughout the coal-bearing strata of the limestone series and upper Coal Measures. That there was iron in the water of all the oil shale lagoons is, however, quite evident. The "spent shale" heaps from the oilworks always become bright red in colour on exposure to air on account of the oxidation of the iron which is uniformly disseminated in small quantities throughout the material. The iron was precipitated in regular minute quantities along with the mud and organic matter, but never became concentrated enough to produce seams, as it did in the later times of the Coal Measures. The explanation of this may be that the oil shale lagoons were deeper than the swamps of the later period, and the deposit of material was too rapid and regular to allow the iron time to accumulate in separate layers which were comparatively unmixed with foreign materials.

Volcanic Activity.—The gloom and monotony of life in these dismal swamps and stagnant forest pools was, however, sometimes dramatically broken by sudden volcanic explosions of great violence. There is clear evidence that the subterranean fires were never quite extinct during the Carboniferous Limestone age, in the West Lothian area. We find in the Bathgate and Linlithgow hills the remains of a deep bank made up of basalt lava streams and beds of

A SCENE IN THE LOTHIAN DISTRICT IN THE CARBONIFEROUS LIMESTONE PERIOD.

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ash more than 1500 feet thick, which were thrown out while the coals and ironstones were being formed in the neighbouring lagoons and swamps. Periodically the serenity of the sleepy hollows and their inhabitants was rudely interrupted by one of these destructive convulsions of nature. The ground shook and the air became dark with clouds of dust and ashes as the dormant volcano burst forth once more and blew to splinters the trees that clothed its slopes, burying the shattered fragments among the debris which fell around the cone. A flood of liquid lava on such occasions welled up, and, rushing for miles down the slope, tore through the dense forest beneath. In doing so it carried along uprooted trees and branches, round which the molten rock quickly congealed as it finally quenched itself amid clouds of steam in the deeper pools of the adjacent water. The accompanying sketch, with restorations of some of the fossil vegetation of the period, is intended to convey an idea of the landscape at such times of local volcanic activity.

This is no mere flight of imagination, but well substantiated fact. I have both visited modern volcanoes and had many opportunities of studying the evidences of ancient volcanic action in the Linlithgow and Bo'ness district, above as well as below the ground. Quite lately I have been able to substantiate the following curious discovery, made originally in 1890, which helps to throw light on a fragment of the mysterious history of that far-off and sometimes very fiery period.

The Bo'ness and Bathgate coalfields of West Lothian are situated respectively on the north and south flanks of the volcanic ridge which was thrown up during the Carboniferous Limestone period, and formed a local barrier which completely separated the two areas of deposition. In the Bo'ness district some of the coal seams are separated by thick beds of basalt. Most of these are true lavas which were not injected into the strata from below, but were poured out over the surface at successive intervals of time, between which the volcano was in a dormant or less active condition. After a long period of quiescence, during which several important seams of coal

and ironstone were produced, including the one with the fossil stumps already referred to, there was a sudden eruption which covered the whole district for many square miles with a bed of basaltic lava. This has been pierced in recent times by a large number of bores and pits sunk to the lower seams, and it has therefore been well exposed for geological investigation. It also crops out on the surface and has been quarried in several places for road metal.

Fossils in Lava Streams.—In 1890 I had occasion to quarry away part of this rock while making some estate improvements at Cowdenhill at the east end of Bo'ness, and was surprised to find embedded in the massive whinstone, some feet from its upper surface, what appeared to be a piece of a fossil tree about a foot long, of which the appended plate is a photograph. I submitted the specimen to Dr. R. Kidston, F.R.S., who agreed with me that it was a piece of a lycopod, although on making microscopic examination of a thin section no internal woody structure was visible. This was, I believe, the first time traces of fossil wood had been found in the middle of what had been originally a molten Carboniferous lava stream.[1]

While travelling in Mexico in 1906, a clear proof came to my notice that such a phenomenon was not unique. In the Museum in Morelia in the State of Michoacan, among other illustrations of local volcanic action, there was a block of scoria or spongy basalt full of charred heads of maize, the shape of which was perfectly natural and unaltered. Some centuries ago a cultivated field of ripe maize in the neighbourhood had been overwhelmed with lava which had cooled so quickly round the heads of corn that they had not time to become burnt up before the matrix became solid. Different instances have lately been recorded of lava streams on Etna, Kilauea, and other volcanoes which have overflowed forests and consolidated round standing trees without destroying them, but I venture to think

[1] The occurrence was described in *Trans. Ed. Geol. Soc.* Vol. VI. 1892, pp. 191-3.

PLANT REMAINS IN CARBONIFEROUS BASALT DISCOVERED IN 1890.

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that unless this had actually been observed occurring in modern times very few people would believe the phenomenon possible. During recent eruptions of Vesuvius and Etna the lava has been seen to consolidate round erect trees in the same way.[1]

The remainder of the rock at Cowdenhill was quarried away in 1910, and I gave orders to the workmen to look out for the rest of the tree which had been first discovered in 1890. Sure enough, there it was, and bits were produced at once, far more of them than I had expected to come across. Some were over 2 feet long, and they were sticking through the rock in all positions. The one being inspected by the writer in the illustration was in a vertical position, and was about 2 inches in diameter. We did not find the main stem, but the numerous pieces of branches, straight, bent or forked, left no doubt as to their origin. They were all entirely mineralised and full of well crystallised calcite and quartz, with no traces left of coaly matter or vegetable structure in the interior. (See frontispiece.)

An Old Lava Stream.—This lava stream is interesting otherwise, and it can be followed through the coalfield continuously for a distance of three miles in one direction, as far as from Arthur's Seat to the point of Leith Pier. At the south-west end towards the volcanic orifice it is about 75 feet thick, and as we trace it northwards in pits and bores, it gradually diminishes till it is only a mere driblet of 2 or 3 feet in thickness under the sea opposite Carriden. Another interesting point may be noted here. There is a seam 3 feet thick known as the Red Coal, which in the northern part of the field at Bridgeness is covered by forty feet of sandstone lying immediately under the basalt. The upper part of the sandstone has been partly fused by the hot lava into an excessively hard, flinty band of rock. As we go southwards this becomes steadily thinner, until at the end of three miles it disappears altogether. The basalt at this spot is found lying

[1] *Vide* B. Hobson and Dr. M. M. Solórzano, *Geol. Mag.* Decade V. Vol. IV. 1897, pp. 217-219. The accompanying photo, taken from Mr. Hobson's paper, was made during our visit to Morelia.

directly on the coal seam, which is greatly injured and disturbed, but has not been altogether destroyed by the eruption.

It is clear that this outburst was a sudden affair, and the liquid flood ran quickly down the slope in a very fluid state, and overspread a considerable area in a few hours or perhaps minutes, before it cooled and consolidated. The forest was still growing on the upper part of the slope, and the lava caught up and carried away some of the trees which it met in its destructive path. But as the lava stream rushed onwards it became gradually separated from the coal which had begun some time before to sink below the water. The submerged coal was at the same time being covered with a bed of sand which increased in thickness as it receded from the volcano. We thus conclude that at the time of the eruption part of the forest was still growing on the land, and that part of it in another place had sunk beneath forty feet or more of water, and was being quickly buried under younger strata.

An Ancient Foreshore.—The movement of this part of the earth's crust can thus be proved to have been irregular, particularly in places where volcanic action was rife. The water was not very deep, since the sandstone in question, at a place somewhat nearer the ancient shore where there is now a quarry, shows ripple marks, casts of fresh-water shells, vestiges of fucoids or seaweed and little heaps of flattened worm castings such as are seen on most sandy foreshores at low tide. In the upper part next the basalt the sandstone is full of stigmaria roots and carbonaceous stems of the trees of the period. Here we thus have another indication that there were tides in the Carboniferous estuary, a point which is not generally easy for geologists to demonstrate satisfactorily. Worm castings on ripple marks of sand cannot be produced under water, or on perfectly dry land. They require a shore alternately submerged and exposed. The ripple marks ran from north-east to south-west in the upper beds of the quarry, indicating that the prevailing waves or currents were from the north-west. The accompanying photograph, taken

BASALT SCORIA CONTAINING CHARRED HEADS OF MAIZE.

Preserved in the Michoacan Museum, Mexico.

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by Dr. W. T. Gordon of Edinburgh University, where the specimen is now preserved, shows the surface of a slab of this ripple marked sandstone with the worm castings on it.

Volcanic Islands.—The effect of this eruption was to stop the deposit of sand, and apparently also to produce a pause in the subsidence of the sea-bed. In sinking a pit near low-water mark at Bridgeness to the Red coal in 1878 the whinstone was found to be only 8 feet thick. It was also observed that the upper part was highly amygdaloidal and full of cavities of calcspar and quartz, originally steamholes in a slaggy, frothy surface. The rock was pale green in colour and much decomposed, and passed imperceptibly up into a fine bed of "calmstone" or white clay full of beautiful fern leaves and other plant remains. It was clear that the old lava stream had lain exposed to the air for a time, and had begun to crumble into clay on which vegetation had taken root, or at least that it had not been covered up with sediment of any kind for a long time after the eruption.[1]

Other and more violent outbursts took place from time to time, and some of the individual lava streams were more than 200 feet in thickness. The basalt was, as in the former case, often left bare for long periods during which the luxuriant vegetation of the time grew and flourished in the pools on its surface and accumulated so as to produce local seams of coal, very thick at places but patchy and irregularly distributed. The Wandering Coal, a most erratic seam, and the Wester Main, situated some distance higher up, have a whinstone roof and pavement in the southern part of the Bo'ness coalfield. Indeed, the high ground of Erngath or Bonnytoun Hill, overlooking Linlithgow, is largely made up of beds of whinstone alternating with seams of impure coal or coaly clay representing old land surfaces on which vegetation grew between the eruptions.

[1] *Vide* H. M. Cadell, "The Volcanic Rocks of Bo'ness Coalfield," *Trans. Ed. Geol. Soc.* Vol. III. 1880, p. 306.

That part of the district was never long under water, and if we go a mile further to the south and west we come to a thick fragmentary deposit in the bed of the River Avon at Little Mill, which was lately pierced by a bore to a depth of some 1300 feet, and was found to consist of almost nothing but ash and other purely volcanic rocks. The ash is pebbly and fine-grained but full of scoriae, large volcanic bombs and blocks evidently dropped from a neighbouring crater among the dust and cinders falling round the cone. Traces of wood are to be found in the rock represented by calcareous casts of splinters of wood sometimes eight inches long. In another outcrop of tuff (a volcanic neck) at St Magdalene's, at the east end of Linlithgow, large fragments are to be found of black petrified coniferous wood showing distinct annual rings of growth a quarter of an inch broad, and quite different in character from the lycopodiaceous wood of the neighbouring coalfields.[1]

The upper part of the ash in the river Avon passes under the Index Limestone, one of the marine bands which are found near the top of the Carboniferous Limestone Measures. This proves that the old volcano, which had managed to keep its head above water so long, at last sank under the sea and became dormant so that it could be covered over with beds of sedimentary material. The eruptions did not cease altogether in the district, as we find one or two small beds of whinstone above the Index Limestone, but they represent only the last expiring efforts of a long era of volcanic activity which ended before the close of the Carboniferous Limestone period, and never again returned to disturb what was afterwards the Forth Valley.

We do not know the whole extent of country which was affected by these eruptions, but the area was far larger than that covered by the existing patches of volcanic rock. The lavas dip to the west in the west part of Linlithgowshire, and disappear under more recent

[1] These fragments were, I believe, first noticed by Hugh Miller, when learning banking in Linlithgow, and are referred to in *My Schools and Schoolmasters*, 1907 ed. Chap. XXIII. p. 509.

PIECE OF A CARBONIFEROUS FORESHORE NEAR BO'NESS.

Ripple-marked Sandstone with Worm Castings.

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strata, so that what lies below can only be revealed by boring. A very deep bore was made in the Carse in 1902, one mile west of Kinneil Colliery, which went down to a depth of 2552 feet through the position of the whole of the upper and lower coals of the Bo'ness field, and pierced an enormous thickness of basalt lavas and beds of ash with hardly any seams of coal or useful minerals. This proves that the main centres of volcanic activity lay somewhere to the west, and that the Bathgate and Linlithgowshire hills are only the tilted-up eastern edge of what may have been a very large volcanic area.

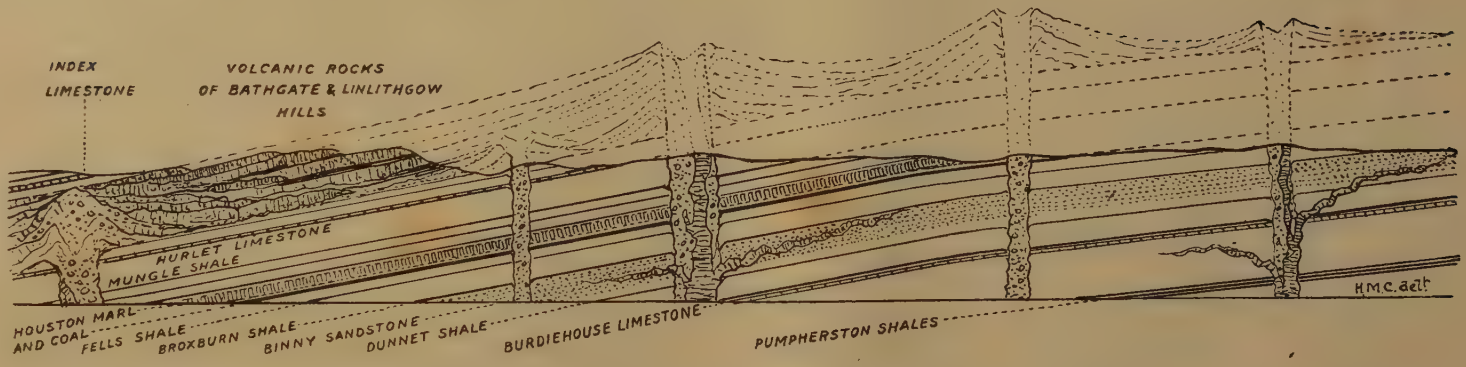
These eruptions were confined to West Lothian, and the Bo'ness lavas are hardly found extending as far north as the Fife Coast. But the Saline Hills are the remains of another local group of volcanoes in activity at the same period in the Fife area.

Volcanic Necks.—That the country further east was also devastated by volcanic eruptions is probable from the fact that at several places, such as Binns Hill, Niddrie Castle, Gallows Crook, near Philpstoun, Tar Hill, at Ecclesmachan, and elsewhere, we find the older rocks of the Oil Shale series pierced locally by vertical columns of tuff which are nothing but the pipes of old volcanoes plugged up with solid ash and scoria. The upper parts of these have all been washed away, but they must have had an orifice somewhere from which to spout out their contents and relieve the internal pressure. They were in activity after the time of the Houston Coal, and do not belong to the explosive period of the Houston marl, already described. Most likely they are the buried roots of the Carboniferous Limestone volcanoes. The section (p. 32) explains how they may have been connected with the volcanic outbursts of the Linlithgow and Bathgate hills. The principal necks are shown on the map at p. 36.

Some of these knobs of ash are only exposed at the surface of the ground, and some are not seen at all, and until recently the fact that they were the outcrops of vertical plugs descending to unknown depths through the strata was more or less of a geological supposition. But the correctness of this inference was practically established in 1896 in

GENERALISED SECTION ACROSS THE WEST LOTHIAN SHALEFIELD.

Extending eastwards from the Avon, near Linlithgow, for about 7 miles.



In this section the relative positions of the volcanic rocks and the principal strata and shale seams are diagrammatically exhibited. The local dislocations and undulations of the rocks are left out, and the section is simplified and restored to show how the ash necks piercing the shalefield may have been originally connected with the main volcanic bank of the Bathgate and Linlithgow Hills. The dotted upper part has been all denuded away, leaving only the plugs of ash to mark the site of the old volcanic vents. From these necks basalt intrusions were probably injected locally into the surrounding strata in the manner indicated.

the oil shale workings of Messrs. James Ross & Co. at Philpstoun, when a vertical ash neck 360 feet in diameter was met with at Gallows Crook at a depth of 120 feet below the surface of the ground, which at that place was obscured by boulder clay so that no rock could be seen.[1]

Hypodermic Injections.—But we must not forget in connection with these outbursts, that the molten rock being squeezed up from below did not all manage to find vent in violent eruptions at the surface of the ground. Some of it was injected under great pressure into the strata, and wormed its way along the lines where it found least resistance to its progress, but never reached the surface of the ground. Generally the path of least resistance was more or less parallel to the bedding planes of the rock, and sometimes the liquid basalt in its subterranean course came to a place where possibly there was less superincumbent weight of rock than at others. It then swelled into a kind of flat bulb or lens, lifting up the strata above like a wedge, and producing what geologists call a laccolite. At other times it succeeded in cutting vertically across the strata and wandering from one level to another.

This intrusive rock was of course very hot, and wherever it came near a bed of oil shale or coal it did a great deal of damage. The shale, as we shall afterwards see, does not contain any oil or oily substances in reality, but only fossilised organic matter occurring in the form of what has been named *kerogen, which only changes into oily hydrocarbons when heated.* The heat of these ancient eruptions did what human beings found out how to do ages afterwards. It distilled the shale, and produced petroleum and wax which remained in the pores and crannies in the adjacent rock. Needless to say there is little or nothing of value left for man to extract from the shale when his work has thus been already forestalled, and at places where intrusive basalt is found near the shale it generally loses all its commercial value. The distilled material is for the most part scattered about in

[1] *Vide* H. M. Cadell, "An Ash Neck in the Broxburn Shale Workings at Philpstoun," *Trans. Ed. Geol. Soc.* Vol. VII. 1899, pp. 477-481.

cracks and interstices in the nearest rock or in the basalt itself, and occurs in too small quantities to be of any practical use. At Broxburn in the Dunnet shale workings there was until recently a small spring of black petroleum oozing from the cracks in a local whinstone intrusion, which has invaded the seam in the Carboniferous period, and thus forestalled the work of man long ago.[1]

These subterranean intrusions are also worthy of notice here from the fact that long afterwards some of them did come up to the light of day. When the sea-bed was upheaved after the Carboniferous period

[1] These are the plain facts of the case, derived from many years of observation and study. But some misguided geologists are to be found who have a theory that all oil, including the oil from shale, is somehow produced chemically in the earth by the help of volcanic or solfataric action, and not by organic life at all. In support of this hypothesis, Mr. Eugene Coste, President of the Canadian Mining Institute, in the *Journal of the Canadian Mining Institute* for March, 1903, actually cites, among other examples, many of which are more or less irrelevant, *my own writings* on the subject. The Scottish shalefields, he concludes (mainly from the geological map), derive their value from the amount of volcanic rock which is seen to occur in the district! Whereas in reality the shale is of value *in spite* of these intrusions, and is richest in places where intrusive or volcanic rock is entirely absent. He says of a paper by me (in the *Trans. of the Institute of Mining Engineers*, Vol. XXII. 1901, on the "Oilshale Fields of the Lothians"): "Therefore the instances cited by Mr. Cadell cannot be regarded otherwise than as most direct evidences that the origin of the oil of the shales is most intimately connected with the very volcanic rocks, in the cavities of which solid remnants of the oil are still left as witnesses. One indeed has only to look at the numerous red spots on Mr. Cadell's map, accompanying his paper, and representing the volcanic rocks and intrusive basalts, evidently younger than the oil shale series, to, at once, understand that this oil district, in which the oil shale quarrying is going on to-day, was, subsequently to the deposition of the shales, subjected to intense volcanism. During and after this great period of volcanic activity the whole district must have been for a long time permeated by solfataric emanations, coming up through the numerous faults, also shown on the map, and many other minor fissures. No doubt these emanations were composed, as we will (*sic*) see all volcanic emanations are, of chloride, including ammonium chloride, hydrocarbons and sulphuretted hydrogen vapors and gases, and this is clearly how these shales got impregnated with the oil now found in them. . . ."

I have seen and heard spouters of natural gas before, but such an eruption of unmitigated nonsense I have seldom had occasion to witness. The fault fissures Mr. Coste refers to were not produced for ages after the oil shales originated, and his other arguments evince a lamentable lack of wisdom and understanding of the whole subject. He might almost as well try to convince us that coal is likewise a volcanic emanation, or that the fossil fishes in the shales came swimming up the imaginary fissures from some vast subterranean reservoir or simmering witches' cauldron, where the elements of synthetic fishes and vegetables are lying ready to unite and spring into life whenever there is an opening made for them to ascend into the upper world.

and the old sedimentary covering thousands of feet in depth was worn away, they were left projecting through the softer rock like knots in an old floor. In later ages they served to give character and diversity to what might otherwise have been but a tame and uninteresting landscape. Binny Craig, Dundas Hill, Inchgarvie, the Bass Rock, Edinburgh and Stirling Castle rocks and the Abbey Craig—all these belong to this category, and what would the Forth Valley, its scenery and history, have been without them?

All these old volcanoes at last sank below the salt sea, and their loose ashes were washed down, re-sorted by the waves, and covered over by beds of shelly limestone and other strata. The limestones pass under beds of coarse sandstone and fine conglomerate known as the Millstone Grit, which show that there were now more powerful currents at work, capable at times of sweeping along grains of sand and gravel, and carrying away most of the finer mud to a greater distance from the shore. The Millstone Grit is a widely disseminated and comparatively barren stratum, a few hundred feet thick, extending over Fife, the Lothians, and Stirlingshire. It contains no coal seams of importance, and produces poor land where it crops out, hence its designation the Moor Rock in some moorland districts where it is particularly thick.

There are here, besides sandstone, some bands of fireclay and poor ironstone. The highest and best of the latter—the Slatey Band seam—is taken as the index bed to mark the top of the Moor Rock and the base of the upper or true Coal Measures, containing the thickest and best coal seams in the country.

It is not intended here to describe minutely the history of the Coal Measure period during which dense forests flourished over most of what is now the land south of the Grampians as well as on the land which now forms England and Ireland. The deep limestone sea in the south became shallow, and gave place to vast swamps and jungles which in time grew rank, sank down and were covered up by sediment, to be succeeded by more forest growths that went through

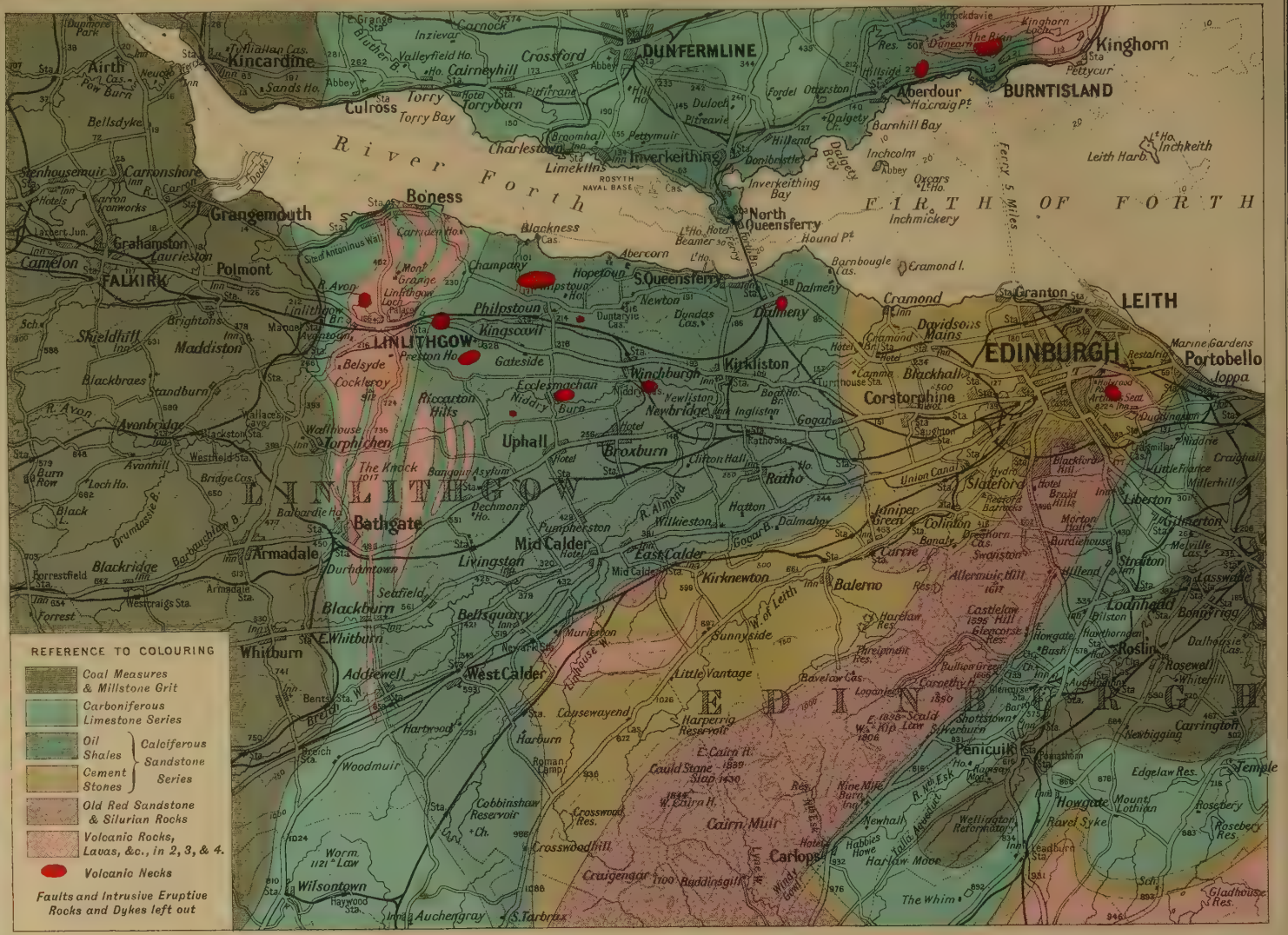
the same cycle for a long succession of ages. In this district no volcanic eruptions or great convulsions of nature intervened to break the dull monotony of that remarkable age, and generations of forests lived in peace and safety, died and were decently buried in their native habitations.

Thickness of the Coal Formation.—The expression "Coal Basins" is well known, and some, no doubt, suppose that the coal was formed in basin-shaped hollows at first. But this is not so. These old forests and bogs and pools of irony water were perfectly flat places originally, and the whole surface of the estuary or mud flats of the time were constantly sinking downwards and being filled up with sediment from an ancient land which has entirely disappeared. The amount of sediment that accumulated in this way and was buried in the seabed of the period was prodigious. If we were to bore from the top of the Coal Measures of the Lothians down through the Millstone Grit, Limestone series and Oil Shales to the top of the Old Red Sandstone with which we started at the beginning of this chapter, we should find that the thickness of the whole Carboniferous formation is no less than 9,000 feet.

This and some other points I have referred to will be best understood by reference to the accompanying vertical section which shows in a generalised way the more important divisions and horizons of the formation.[1] In England and Wales the thickness is far more than 9,000 feet. If all this rock had been washed away from some older land and spread out to such a great depth over many hundreds of thousands of square miles of the earth's surface, we can faintly imagine the size of the lost continent from which it has all been derived!

[1] *Vide* section at page 15.

GEOLOGICAL SKETCH MAP OF OILSHALEFIELDS OF THE LOTHIANS


REFERENCE TO COLOURING
Coal Measures & Millstone Grit
Carboniferous Limestone Series
Oil Shales
Cement Stones
Calciferous Sandstone Series
Old Red Sandstone & Silurian Rocks
Volcanic Rocks, Lavas, &c., in 2, 3, & 4.
Volcanic Necks
Faults and Intrusive Eruptive Rocks and Dykes left out
River Forth
FIRTH OF FORTH
LINLITHGOW
EDINBURGH
DUNFERMLINE
BURNTISLAND
LEITH
Kincardine
Culross
Inverkeithing
Rosyth Naval Base
Boness
Grangemouth
Falkirk
Linlithgow
Bathgate
Armadale
Whitburn
West Calder
Mid Calder
Livingston
Uphall
Broxburn
Kirkliston
Corstorphine
Penicuik
Carlops
Kinghorn
Aberdour
North Queensferry
Inchkeith
Inchmickery
Cramond I.
Barnbougle Cas.
Hound Pt.
Granton
Portobello
Joppa
Musselburgh
Dalkeith
Roslin
Loanhead
Gilmerton
Liberton
Colinton
Slateford
Juniper Green
Currie
Balerno
Kirknewton
Ratho
Newbridge
Winchburgh
Gateside
Kingscavil
Philpstoun
Champany
Abercorn
Blackness
Carriden
Dalmeny
S. Queensferry
Hopetoun
Cramond
Davidsons Mains
Blackhall
Craiglockhart
Craigleith
Granton
Leith Harb.
Pettycur
Kinghorn
Aberdour
Burntisland
Dysart
Pettymuir
Limekilns
Charlestown
Torryburn
Torry
Culross
Torry Bay
Valleyfield
Cairneyhill
Crossford
Carnock
Oakley
Comrie
Saline
Blairadam
Kelty
Lochgelly
Cowdenbeath
Dunfermline
Townhill
Pittencrieff
Duloch
Pittreavie
Dalgety
Dalgety Bay
Donibristle
Hillend
Inverkeithing Bay
Barnhill Bay
Inchcolm
Oxcars
Aberdour
Haiscraig Pt.
Fordel
Otterston
Hillside
Dunearn
The Ruin
Knockdavie
Kinghorn Loch
Pettycur
Leith Harb.
Inchkeith
Ferry 5 Miles
Forth Bridge
Queensferry
Hopetoun
Abercorn
Barnbougle
Cramond I.
Hound Pt.
Dalmeny
Newton
Dundas Cas.
Duntarvie Cas.
Niddry Cas.
Niddry Burn
Newliston
Ingliston
Gogar
Broxburn
Clifton Hall
Ratho
Hatton
Wilkieston
Gogar-B.
Dalmahoy
Juniper Green
Colinton
Slateford
Union Canal
Hydro
Blackford Hill
Braid Hills
Morton Hall
Burdiehouse
Swanston
Allermuir Hill
Hillend
Glencorse
Howgate
Bush
Auchendinny
Carlops
Penicuik
Roslin
Rosewell
Whitehill
Loanhead
Bonnyrigg
Lasswade
Dalhousie Cas.
Carrington
Newbigging
Temple
Edgelaw Res.
Howgate
Mount Lothian
Rosebery
Rosebery Res.
Ravel Syke
Wellington Reformatory
Talla Aqueduct
R. North Esk
Kine Mire Burn
Newhall
Cairn Muir
Cairn Hill
Scald Law
Kip Law
Shottstown
Henburn
Harperrig Reservoir
Carlops
Headburn
Harlaw Moor
Windy Gowl
Craigengar
Two Buddinsgill
The Whim
Crosswood Res.
Crosswoodhill
Cobbinshaw Reservoir
Woodmuir
Harburn
Roman Camp
Caerketton Cas.
Caerketton Hill
Allermuir Hill
Castlelaw
Glencorse Res.
Harlaw Res.
Threipmuir Res.
Bullion Green
Logan Ho.
Carnethy
Scald Law
Kip Law
Shottstown
Henburn
Harperrig Res.
Causewayend
Little Vantage
Sunnyside
W. of Leith
Murieston
Newark Sta.
Addiewell
Seafield
Blackburn
Bellsquarry
Durhamtown
Mid Calder
East Calder
Livingston
Pumpherston
Dechmont
Bathgate
Armadale
Blackridge
Torphichen
Wallhouse
Riccarton Hills
Niddry Burn
Ecclesmachan
Winchburgh
Kirkliston
Gateside
Kingscavil
Philpstoun
Champany
Abercorn
Blackness
Carriden
Dalmeny
S. Queensferry
Hopetoun
Cramond
Granton
Leith
Edinburgh
Portobello
Joppa
Musselburgh
Dalkeith
Roslin
Loanhead
Gilmerton
Liberton
Colinton
Slateford
Juniper Green
Currie
Balerno
Kirknewton
Ratho
Newbridge
Winchburgh

CHAPTER III.

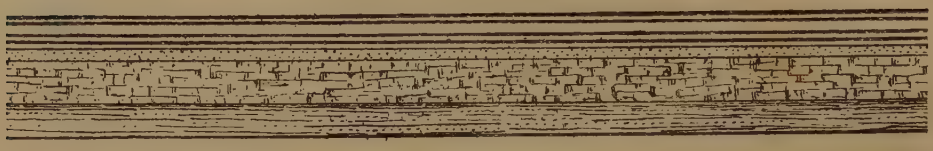
ANCIENT LAND AGITATIONS.

BUT how were the coal basins produced? It is a long lane that has no turning, and to this long story there was at last an end. The climate changed and the steady subsidence finally came to a stop as great terrestrial movements set in. No more deposits were made in the ancient bank. The earth's crust in the British area was squeezed together by pressure from below and crumpled into wave-like swellings. The strata were thrown into long troughs and arches, shaken by earthquakes, and rent by vast fissures that gave the heaving ground relief along certain lines. Great blocks of land were made to rise on one side like steps and terraces, or sink far downwards on the other into the bosom of the perturbed earth.

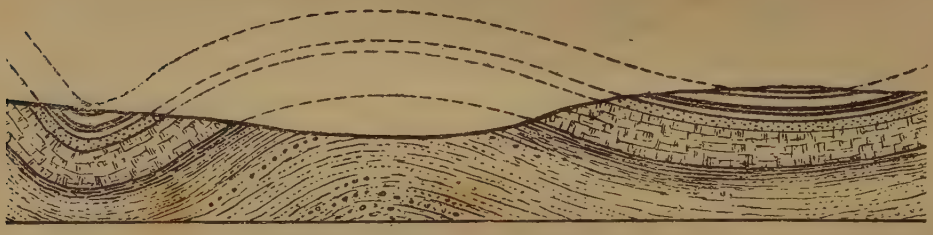
Coal Basins.—As soon as the newly formed rock surface emerged and rose above sea level it was attacked by the weather and the running water, and then the process of denudation began. The higher parts were gradually worn down and carried away by the rivers to make new formations in the sea, just as the land itself had been constructed out of the debris of the vanished country that had preceded it. Examples of the wearing away of the land and the scooping out of the surface by rivers will be given in another chapter.

What we have to notice now is the origin of coal basins. When the tops of the arches were washed away, and the crests of the earth waves were broken by faults, all that remained intact were the buried parts, and these were perhaps hidden too deep below sea level to be

completely removed by the denuding forces. We thus find coal basins or troughs produced by faults in the depths of which the strata have been preserved in the way shown in the diagram. But these occur only in comparatively few places. By far the greater part of the original Carboniferous formation has been removed in the ages which have elapsed between that period and our own.



Strata as originally formed.



Strata after folding and denudation.

ORIGIN OF COAL BASINS.

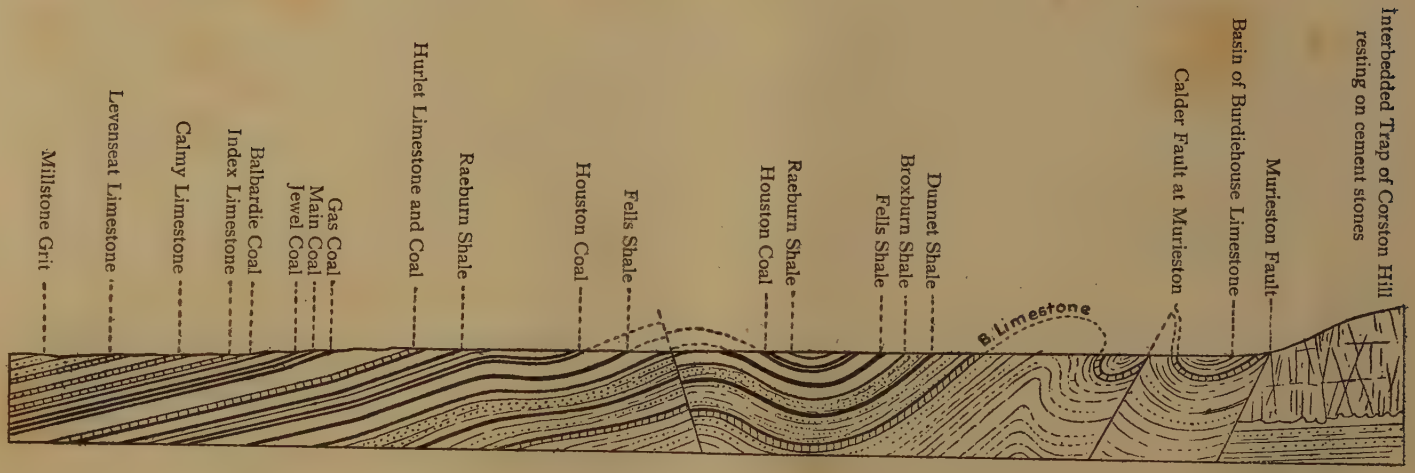
A large part of the coalfields of both Scotland and England has been removed, but not all, and it behoves us to make the best we can of the small patches that remain of what was probably once a wellnigh universal covering in this region. The Midlothian coalfield, for example, is only the bottom of a trough between two great arches, the crests of which have been entirely washed away. The oil shale fields occupying the centre of the western arch have been laid bare, but before denudation had gone so deep some 4,000 feet of rock had to be removed, including, no doubt, a great deal of valuable coal and ironstone, as the accompanying diagram will serve to explain.

Besides the crumpling of the strata by pressure from the sides, the earth movement produced enormous "faults," which rent the surface along certain lines, and these have given rise to several of the most important physical features in the Forth Valley. For example, there is a great line of displacement along the east side of the Pentland ridge which has had the effect of lifting up the older rocks on the west side like a gigantic step against which the newer strata of the Midlothian coalfield abut on the low ground to the east.

Along the north-west flank of the Pentland ridge there are likewise conspicuous lines of faulting, and the oil shales have been thrown into a series of violent undulations in connection with these movements of the earth's crust. The section on next page, extending for seven miles from Murieston, near Mid Calder, to the West Calder district, shows that the faulting and crumpling was less violent towards the west. In the West Calder shalefield, three miles south of Bathgate, the strata are found to dip regularly to the west under the Carboniferous Limestone, and the complicated basins and arches that characterise the central shalefields of West Lothian entirely disappear in that quarter. It is further to be noted that there is only one thin bed of volcanic rock among the limestone and coal seams west of West Calder. The volcanic action of the Carboniferous Limestone period did not extend much further south than Blackburn, and no ash necks are found penetrating the shalefields in this district, as can be seen by a reference to the map at p. 36.

Another huge fault runs along the foot of the Ochils in the Devon Valley. The deep-lying Old Red Sandstone lavas of the range have thus been lifted up to the light of day once more and made to abut against the far younger Coal Measure strata of the Alloa coalfield. But the very highest of the lavas, as we have seen, are situated at least 9,000 feet below the top of the Scottish Coal Measures. In other words, if we were to bore on the low ground next the Ochils down through the rocks of the Alloa coalfield, we should have to go 9,000 feet, and perhaps far deeper, before we came

GENERAL SECTION OF THE WEST CALDER SHALEFIELD AND CARBONIFEROUS LIMESTONE SERIES TO THE WEST. (7 MILES.)



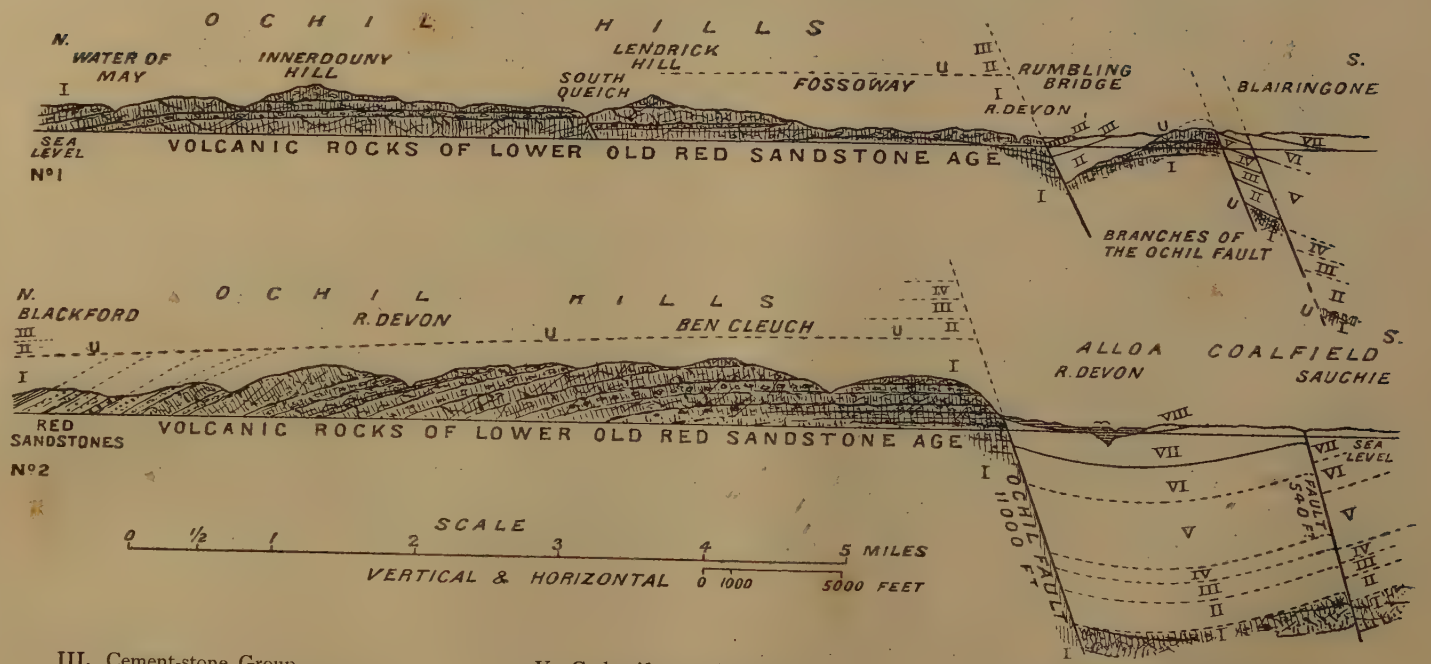
This section shows how the dislocations and folding of the strata diminish and disappear towards the west where the oil shales dip with a regular inclination under the Carboniferous Limestone series.

to the very rocks of the Ochils that rise above us to a height of 2,000 feet on the north side of the Devon Valley. The original forests and mud-flats of the Carboniferous period did not end abruptly at the base of the Ochils. If this had been the shore line at that time, we should find the Coal Measures to be full of conglomerate beds made up of fragments of the ancient lavas which had been washed down like the debris on the beach and interbedded with Carboniferous strata. It is clear, on the contrary, that the Coal Measures once extended for some distance right over the lava beds of the Ochils. These strata are not now to be found on the top of the hills because, being lifted so high, they have long ago been washed away. It is also clear that only the part which was deeply buried on the downthrow side of the fault, and thus protected from erosion, has escaped the besom of destruction that has swept all the higher districts bare. The Ochils themselves would have been levelled down had they not been made up of hard and durable volcanic rock. There must have been terrific earthquakes when the uplift was taking place, and even yet every now and then slight shocks occur at the Bridge of Allan, Comrie and other places on the lines of these ancient Scottish dislocations. These show that after millions of years have passed the grinding movement of the displaced strata has not even yet entirely ceased.

To illustrate this point clearly and graphically, I am indebted to Dr. B. N. Peach, F.R.S., for drawing the accompanying accurate sections across the Ochils (on a natural scale of 1 inch to a mile), showing the dimensions of this enormous displacement at the Rumbling Bridge and near Dollar respectively. In the case of the single fault shown on section No. 2 the amount of downthrow (or uplift) is no less than 11,000 feet, or over two miles!

This chapter in the record of the solid rocks comes to a natural termination here, and the geological sequence of events in the Forth Valley closes when we reach the highest or red strata at the top of the Coal Measures.

SECTIONS ACROSS THE GREAT OCHIL FAULT. (By Dr. B. N. Peach.)



III. Cement-stone Group.
II. Upper } Old Red Sandstone.
I. Lower }

V. Carboniferous Limestone.
IV. Campsie Volcanic Rocks.
III. Cauldron Linn Dolerite.

VIII. Upper Red Coal Measures.
VII. Productive Coal Measures.
VI. Millstone Grit.

U U. Unconformable junction line on which Upper Old Red Sandstone rests.

Photo by A. Drysdale.

A VIEW ACROSS THE DEVON VALLEY.

Showing the South Face of the Ochils along the Line of the Great Fault.

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Between the Carboniferous age and the relatively modern period in which the River Forth came into existence there is a vast hiatus in the geological record. Indeed, we find here no newer rocks at all until we come to the glacial clays and gravels of comparatively recent times. At other places we know that the Coal Measures continued to sink and were buried under the New Red Sandstone, Jurassic rocks, Chalk, and Tertiary formations in succession; but if any of these rocks were ever formed here they have all been washed away long ago, leaving not a vestige behind.

A Plain of Denudation or Peneplain.—So far as the evidence goes, the broken and crumpled Carboniferous strata during that long break in the geological record were squeezed up into a high and dry land surface, which the rain and weather began to attack as soon as the rocks showed their heads above water. This old continent suffered enormous denudation in the vast aeons of time during which it remained exposed to the powers of the air. The final result of the process was that it became planed down almost to sea level, and when once it had become so far degraded the sea protected it from further erosion. Such a worn down denuded surface is known to geologists as a *Peneplain.*

I have seen in the tropical deserts of Western Australia a modern peneplain recently upheaved from the sea. The North Western corner of that dismal region is for thousands of square miles a perfectly flat expanse of sand-swept rock, mostly gneiss, slates, and granite, containing some veins of gold-quartz and other precious minerals. It is very little above sea level, and the dreary monotony of the landscape is broken only by occasional projecting knobs of hard red rock sticking up like knots on an old floor, evidently the remains of islands that had not been washed away before the last upheaval laid bare the shallow sea-bed.[1]

This idea of a peneplain, such as would be the condition of all our

[1] *Vide* H. M. Cadell, on "Some Geological Features of the Coast of Western Australia," *Trans. Ed. Geol. Soc.* Vol. VII. 1897, p. 181.

land if left to the unrestrained action of the atmosphere and the running waters, is an important thing to consider. There are many other proofs of such a planing down of ancient land surfaces in past times by the long-continued action of erosion, both in this country and elsewhere. And if there had not been at the same time upheavals constantly going on at other places, the whole of the earth's surface would in time be reduced to sea level or flattened out to huge sandbanks just "awash," and only fit for crocodiles and turtles to eke out a miserable existence upon. In the oldest part of the kingdom between Cape Wrath and Assynt we find remains of a very ancient floor of this kind under the Cambrian quartzite in some of the wonderful mountains of that wild region. Fragments of a primeval continent of gneiss and red Torridon sandstone are to be seen where the original rugged land has been planed down as flat as a table, and then covered over by a perfectly new formation of white quartzite. The whole region was afterwards upheaved and the old peneplain tilted up and exposed to the light of day on the mountain sides.[1]

Although this has happened in places, the face of the whole earth has not, happily, yet reached such a dead level of degradation, and movements of upheaval have been constantly counteracting the effects of denudation. If astronomers are to be believed, this however is something like the present condition of the planet Mars. The whole of the Martian land appears to be a vast dry plain of brown soil, with no rivers, seas, mountains, or plateaus on its bare, flat surface. The beings who inhabit it appear to spend their lives in digging a network of marvellous canals to convey to the lower latitudes such water as can be collected from the melting snows at the poles, and in working incessantly at the pumps to keep the irrigation water always flowing. The canals and "oases" at their intersections appear greenish at certain seasons. This lends additional colour to the hypothesis which has been advanced, and the fact that the lines

[1] Vide *Geological Survey Memoir on the North-West Highlands*, 1907, p. 369.

are mathematically straight for vast distances shows that the land is perfectly level. Indeed, if the lines are water channels at all, the ground cannot be other than flat whether they be straight or not. Such alas! may perhaps be the unhappy fate in store for our remote descendants—among whom, however, there will be no such thing as unemployment when all hands will have to be at the pumps for dear life. But Providence has been kinder to us of this generation, counteracting the dire effects of denudation at one place by a constant process of upheaval at another.

In the case of the Forth we have, I believe, to do with the remains of an old peneplain such as I have described, in which all the rocks, hard and soft, were levelled down to a uniform more or less even surface, without hills or valleys. This surface was subsequently upheaved *en bloc* without crumpling, but with a gentle slope or "list" towards the East. The West edge facing the ocean was steep and high, and may have been bounded by enormous faults or displacements, giving rise to one or more great steps down into the bed of the Atlantic. This desk-like configuration of the part of the earth's crust which afterwards became the mainland of the United Kingdom, determined the original courses of the Forth and other rivers whose further history we shall discuss in the following chapters.

CHAPTER IV.[1]

RIVERS AND THEIR WAYS.

FROM its first beginnings in the remote ages of the geological past, down to the more recent and better known times of the archæologist, the River Forth has had an interesting and chequered career. The story of the Forth is indeed a long one, and it is not possible in this chapter to do more than attempt to draw some rough and general outlines of what observation and theory lead us to suppose has happened during some special periods in the life of the river.

The ways and habits of streams and running waters have been much studied by geographers in recent years, but it may be well, for the benefit of any readers not specially versed in the lore of physical geography and geology, to begin the argument, like Euclid, with a few elementary postulates and axioms, so that there may be a clear understanding of the reasoning on which the conclusions of the following pages are founded.

Nature is a thing of law and order, and although it may not always be very apparent at first sight, it is the fact that law and order prevail among the living waters of the earth as well as among the inhabitants of the plant and animal kingdoms. When a river is found apparently disobeying some general law and following an irregular and abnormal course, then the philosopher may with profit

[1] This and the two following chapters are reprints, with a few additions, of the "Story of the Forth" in the *Scottish Geographical Magazine*, Vol. XXVIII. 1912, pp. 225-263.

THE CAULDRON LINN.

To face page 46.

consider the matter and try to ascertain the why and wherefore of the unusual phenomenon and what lessons it may have to teach.

When, for example, rain falls on a sloping roof it naturally runs straight down to the rhones, and after a shower if we were to notice that it had apparently run obliquely across the slates or even up towards the ridge we should, no doubt, be much surprised and anxious to trace the cause of such a remarkable and unnatural phenomenon. Now in the case of a river its natural course is a straight line by the shortest route from the watershed to the sea. The original surface of the land after it was first upheaved from the sea, where the solid rocks mostly all originated, was covered with streams all running more or less in the direction of its greatest declivity. By and by the rills began to coalesce into a few larger streams with shallow valleys and tributaries. The tributaries ran towards the sea and the main river, and joined the trunk at a more or less acute angle above the confluence. A normal river is thus like a well-developed tree with branches growing upwards from the stem and stretching towards the light of heaven. Some branches may get more light and become stronger than others, and some tributaries may receive more rain and grow larger than others, until in time the young and symmetrical figure grows into a distorted old patriarch with almost no resemblance to its original form.

These may seem truisms too obvious to be worth mentioning, but as we follow the argument the benefit of referring to them may soon become more apparent. As time goes on the glens grow deeper and larger, and their rivers acquire a prescriptive right of way that becomes ever stronger with the lapse of centuries. Each river has a valley, and there are no dry valleys which have not once been occupied by a river except in a very few abnormal cases. If we find a dry valley it is a proof of some change of circumstances, and to this point we shall return later on.

It must never be forgotten that the rivers have made the valleys, and that it is not the valleys that have determined the courses of the

rivers. The valleys in this country are not due to cracks or sinkings of the surface of the earth's crust—a fact that is easily proved by a little investigation. There are no doubt many cracks and fissures in the rocks, but these run across the country in more or less straight lines, and are never found to wind about like the tortuous meanderings of river beds, nor do they branch from the main stem and subdivide again like the tributaries of a river system. No doubt fissures are occasionally to be found running along the beds of straight river courses for some distance, but this is because fissures mark lines of weakness and broken rock, along which running water, if it happens to be flowing in the same direction, finds it easier to excavate a channel than at places where the rock is quite undisturbed and solid.

The next point to be noted is the three ways in which the rock is worn down. Streams eat their way both downwards into the rock and backwards into the hills, and at a later stage within history they meander (as shown on the sketch) from side to side and widen their valleys like a man with a scythe cutting a broad track across a hayfield.

The Cauldron Linn, as the illustration shows, exemplifies a stream engaged in sawing out a notch in a hard dyke of basalt which crosses the Devon below the picturesque gorge at the Rumbling Bridge. The deposits of sand and gravel brought down from the Ochils in the course of centuries have enabled the water to grind away part of the barrier, and as soon as the hard rib has been entirely sawn through, the fall will recede into the softer sandstone above the dyke and still further deepen the ravine up stream. The fall will eat its way back into the hills, and the more water and gravel coming down, the faster will the recession go on. When the water is low and clear there is practically no erosion, but when the stream is in spate, and full of heavy grit and sediment, it goes on grinding merrily, like a lapidary's wheel with plenty of diamond dust.

THE BAB-EL-KALABSHA ABOVE ASSUAN

Where the Nile has excavated a Channel 108 feet deep in Granitic Rock.

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At the Cauldron Linn and the Rumbling Bridge the work of erosion is more immediately effected by the action of the river in producing so-called *potholes* in the rock. The Cauldron is the largest of these, and the boulders that are washed into it are constantly rolled round by the swirling water so as to grind out the bottom and sides of the cavity, and gradually enlarge it till the down-stream side is entirely worn through, and the water escapes at a lower level.

A Highland Stream widening its Channel.

It is a far cry from the Cauldron Linn to Niagara, but here we see the same process at work on a vastly grander scale. The classic river of the Western continent has been for centuries eating its falls backward from Lake Ontario towards Lake Erie, and from 1842, when measurements were first made, the falls had retreated, up till 1905, a distance of 265 feet, or at the average rate of a little over 4 feet per annum. Had the water been turbid and full of sediment the rate would no doubt have been much more rapid. Issuing, however, as it does in a clear and limpid stream from the great lake above, it can only work on the rock by undermining the soft shale under the limestone ledge, which falls in great blocks and is ground

to powder in the vast cauldron beneath. So rapid is the recession in spite of this want of sediment that the Canadian Fall, formerly known as the Horse Shoe, has completely changed its form, and is now like a sharp letter V pointing up stream. It is much less picturesque now than when I first visited it in 1891, and the remarkable power of the cataract in tearing away and removing the hard rock is most impressive.

From Niagara to the Grand Cañon of the Colorado in Arizona is another far cry, but if we turn to that remote wilderness of the Far West we find a still more impressive example of the erosive power of running water, which this time, however, is far from blue and limpid. The Colorado River has for ages been running like the Nile from a rainy country across a dry desert plateau made up of flat beds of more or less soft rock of brilliant and variegated tints. It has cut its bed down through several geological formations to a depth at places of more than 5000 feet. The seething stream far down at the bottom of this awful abyss is nothing but a rolling mass of sand and mud liable to sudden floods and changes of level and colour. When I was down the cañon in 1891 the water was comparatively low and had the colour and consistency of pease soup. The rocks were evidently being rapidly ground down and rolled along in pieces which would soon be broken up and washed away in grains to the Gulf of California. No intelligent person who has ever seen that marvellous river can doubt for a moment that its gorge has been scooped out in the past by the same processes as are still engaged in its excavation.

The illustration shows the zig-zag line of the cliffs and valley of erosion as contrasted with the straight lines of the cliffs of elevation which follow the course of fault fissures in the plateau.

To change the scene once more, there are rivers which not only deepen their valleys but scoop out enormous holes in them, so that were they to be temporarily dried up, their course would be marked by chains of deep and narrow lakes separated by dry spaces or

THE SECOND DEFILE OF THE IRRAWADDY.

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ridges of rock. The Nile at the Bab-el-Kalabsha, about 30 miles above the great dam of Assuan, runs between granite walls of no great height, but these drop perpendicularly into water 18 fathoms or 108 feet deep, much below the level of the granite at the dam. The hard sand of the desert is blown into the river and swept along the bottom, first downwards and then upwards, as the water shallows, so as in course of time to grind out a long, deep trough which can be produced in no other way than by multitudes of hard grains constantly being dragged along by the powerful current.[1]

A still more striking example of this phase of stream erosion which I have noticed in the course of my travels is to be found in the Second Defile of the Irrawaddy in Burma, a river whose valley is less known, but at some places far more picturesque than that of the famous water of Egypt. The Irrawaddy at the Second Defile, about 600 miles above Rangoon, crosses a range of mountains 4000 feet in height, and as the surface of the water is only 300 feet above sea-level the gap in the mountains is about 3700 feet deep. The river bed in the centre of the defile is full of enormous holes, some of them 27 fathoms, or more than 160 feet, in depth, produced as in the Nile by the swirling, surging current dragging along the grit and soil constantly being washed down from the shoals and jungle-clad alluvial banks upstream.[2]

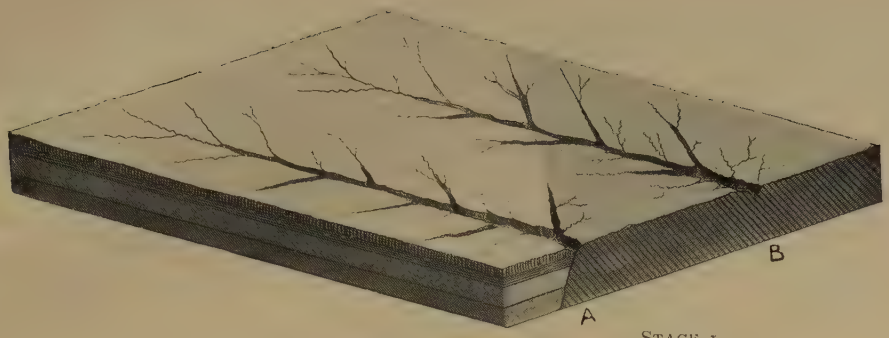
Let us now come a little nearer the proposition under discussion, and, leaving these far-away rivers, consider for a few minutes another and more theoretical part of the question, arising, however, out of what we have been observing, and relating more closely to what falls to be observed at home. To make the subject abundantly clear I have drawn diagrams showing two model rivers, A and B, at four successive stages in their hypothetical history.

[1] *Vide* H. M. Cadell, "The Development of the Nile Valley," *Scot. Geog. Mag.* 1903, p. 233.

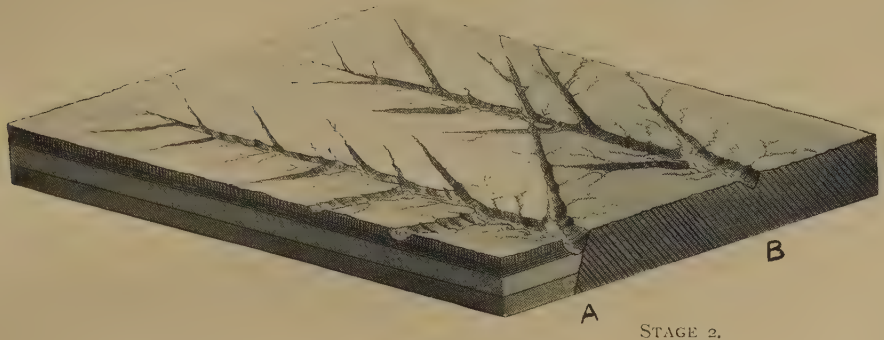
[2] H. M. Cadell, "A Sail down the Irrawaddy," *Scot. Geog. Mag.* 1901, pp. 242-3.

Each river has ten tributaries, five on either bank. River A on the left flows over soft strata that constitute the greater part of the original sloping plateau. River B, let us suppose, has the lower part of its course on hard solid granite, tinted darker on the plan, and hatched in section. The granite area being much more durable than the stratified part of the plateau, B will not be able to deepen its bed nearly so fast as A, and the tributaries of A will therefore eat their way downwards and backwards at the greater rate, as shown in the second figure. By and by the lowest of A's tributaries on the left bank may push its way backwards, as shown in the second diagram. It may follow the line of junction of the hard and soft rocks. This may be a fault fissure easy to excavate, and the stream will in time succeed by virtue of its greater declivity in eating into the water-parting and tapping the headwaters of the nearest of B's tributaries. Nothing succeeds like success, and being thus reinforced with more water, this invader of B's territory may go on and next succeed in tapping the upper part of B's main channel, and end by finally decapitating B altogether and drawing off half of its water into A's domain. B will thus become weaker and weaker, and A will wax in the same proportions as B wanes, and the lowest enterprising tributary of A may end in growing greater than the parent stream itself, as shown in the next figure. This tributary may grow so deep as to end in finally tapping not only B's headwaters, but any part of B's basin it can reach, and in this way the final state of matters will be that the second of B's tributaries on the left bank may be diverted into A's basin, leaving B in a miserable condition with hardly anything to live on but fond memories of departed greatness.

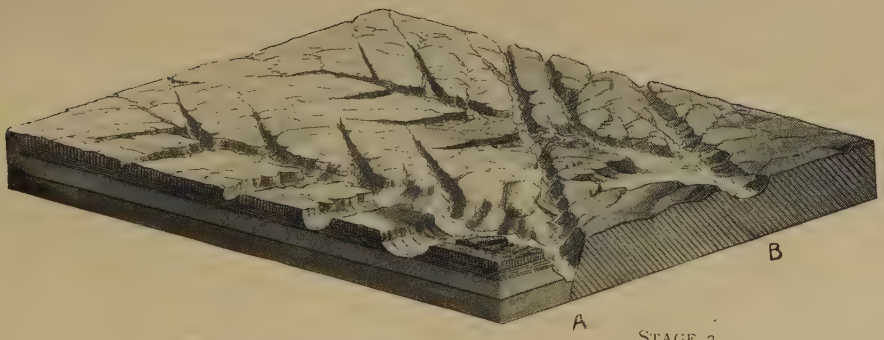
The original course of the main river is described by physical geographers as *consequent*, as it is consequent on the original direction of slope. The course of the later tributaries joining it is similarly known as *subsequent*, but sometimes, as we shall see afterwards, rivers flow in a third direction, neither consequent nor strictly subsequent



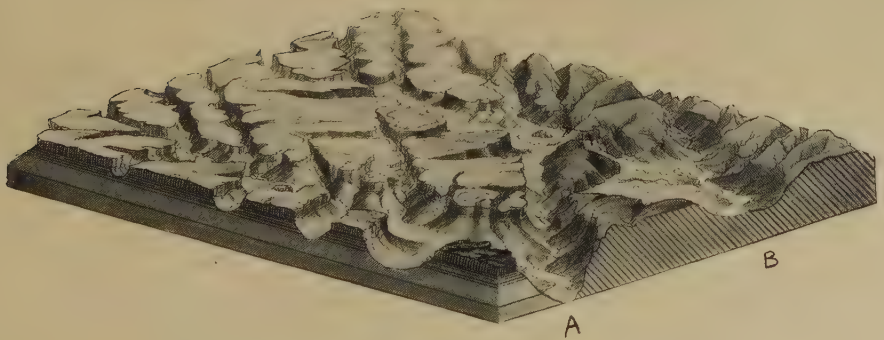
STAGE 1.



STAGE 2.



STAGE 3.



STAGE 4.

FOUR STAGES IN THE DEVELOPMENT OF A RIVER SYSTEM.

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in the sense now used. In the last figure the second tributary of B on its left bank will be seen to have been tapped, so that the water near the confluence with the subsequent tributary of A runs in a direction *against* the slope of the plateau and *opposite* to the original direction of flow of river B. A stream that has thus reversed its course is said to have become *obsequent*, a useful term first proposed by my friend, Professor W. M. Davis of Harvard. It is clear that in time A might become so deep as to draw off the whole of B, and in that case the lower part of B would run backwards against the original direction of slope, and the river become entirely obsequent. Good examples of obsequent streams are to be found in various old river-systems, and particularly in the basin of the Forth and Clyde, to which we shall now return.

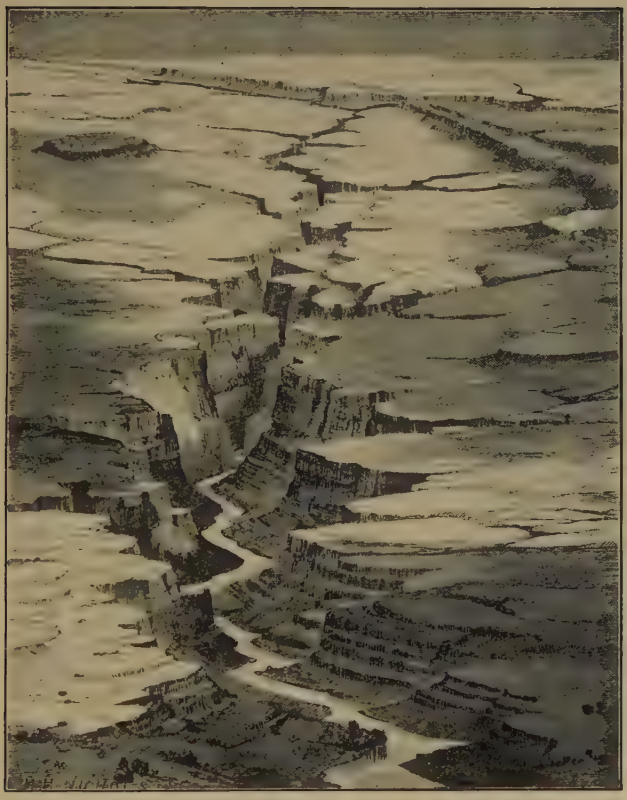
This area also comprises fresh-water and salt-water lochs of much beauty and interest, not only to the tourist in search of scenery and sport, but to the merchant in search of business and the scientist in pursuit of knowledge. These lochs, all more or less long and narrow, are often far deeper than the sea outside, and although mostly outside the Forth district have, as we shall see, a distinct place in the history of that river.

From the point of view of the geological historian, lakes, however they may have originated, are only to be looked upon as temporary and evanescent features of the ever-changing landscape. They constantly receive from the surrounding hills and glens streams of turbid water full of sediment, but the outflowing river is always clear and limpid, all the detritus having been separated in the calm water and left behind as in a filter. Filters, however, become choked up in time, and so do lakes, and the whole country is dotted over with old lake beds that have become overgrown with peat or silted up, many of them within quite recent times. Their outlets have also been deepened by the effluent streams, and the shallower ones may thus have been often drained quite dry. Many countries, like the United States, India, and Australia, have perfectly dry scenery with

none of the glittering spots of fresh water which add so much to the attractiveness of the Scottish landscape.

It is only in countries where lakes have been produced at a comparatively recent time that they still exist in large numbers. Time was when there was none in Scotland, or at least very few in our upland glens and straths, but the Great Ice Age arrived and passed slowly by, covering the land like Greenland with a mantle of solid ice and snow, and when at last the glaciers melted away and the frozen flood subsided, the worn face of the land appeared once more to view, but now all flecked over with bright streaks and pools of shining water.

Countries that have been under ice, such as Canada, Scandinavia, Finland, and Patagonia, are sprinkled over with countless numbers of lakes and tarns, which have some relation to the local river-systems. As rivers of water scoop out hollows in their beds, so do rivers of ice in their valleys, especially where these are narrow and constricted, but ice being much more solid than water, has power to grind down its channel far more effectively. Besides this, the pressure on the bed of a glacier hundreds or even thousands of feet thick, as many of the Scottish glaciers must have been at one period, is far greater than that which the largest river can bring to bear on the gravel it is sweeping along. No doubt, as we have seen, if rivers were to dry up, as they often do in Australia, chains of lakes and pools would be found scattered along their track, but these would be quite insignificant compared to the deep basins in rocks where ice has been at work. The glaciers merely accentuated and deepened the old river valleys, but did not produce new ones. The rivers were on the ground long before the glaciers, which were only temporary tenants that appeared on the scene and occupied the valleys during an important but limited period. While the ice prevailed the rivers' work was suspended and their ordinary habits were changed, but only for a time, to be quickly resumed as soon as the climate again became normal.



GRAND CAÑON OF THE COLORADO.

Showing the zigzag character of cliffs and valley of erosion as contrasted with the straight lines of the cliffs of elevation following the course of fault fissures traversing the plateau some distance back from the river.

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It is thus apparent that, except for the rivers, the ancient Scottish landscape before the ice age was a dry one, and we may leave the lochs out of account and consider them filled up and their beds no more conspicuous than other parts of the glens during the earlier chapters in the ancient history of the Forth.

CHAPTER V.

THE FIRST BEGINNINGS OF THE FORTH.

WHILE engaged on the staff of H.M. Geological Survey, mapping the rocks of the Dumbartonshire Highlands in the district of Loch Lomond and Loch Long, many years ago, my attention was drawn to what seemed a singular feature of the whole river system in that part of the country. The subject had apparently never been discussed before, and I ventured to explain the hypothesis that suggested itself to me in a short paper in the *Scottish Geographical Magazine* for 1886. The general conclusions then arrived at still seem perfectly sound, and in view of the fresh knowledge we now possess of the geographical conditions and facts relating to the physical history and development of rivers and river systems, which have been carefully investigated in recent years by many eminent observers, it may be of interest to return to the subject and pursue it a little further now.

This district, it is to be noted, is not situated within the existing Forth basin, but is entirely drained by the Clyde, and therefore may appear at first sight to have nothing whatever to do with the valley system of the eastern river. On closer scrutiny, however, some important peculiarities soon become apparent. These, as we follow up the line of investigation, lead us to conclude that notable changes have taken place in the local river systems since the stream originated in the middle of the Tertiary age, and that this part of the Argyllshire and Dumbartonshire Highlands had in fact a great deal to do at one time with the Forth and its many tributaries.

THE FORTH & CLYDE BASINS

The Edinburgh Geographical Institute

J.G.Bartholomew

Scale 27 Miles to 1 Inch

0 10 20 30 40

REFERENCE TO COLOURING

Sea level to 250 ft.	250 to 500 ft.	500 to 1000 ft.	1000 to 1500 ft.	1500 to 2000 ft.	above 2000 ft.

WATERSHEDS

On glancing at the map, two topographical features at once arrest our attention in the mountainous district of Cowal and Dumbartonshire, between Loch Lomond and Loch Fyne.

1. With the important exception of the Loch Long depression, the main valleys and glens, including the upper part of the Clyde, have a general trend towards ESE. or SSE.

2. The watersheds between what are now the main valleys are not situated midway between but close to the eastern sides of these glens.

The country between Loch Lomond and Loch Long is a triangular plateau of clay-slate and metamorphic schist, with twelve principal mountains varying in height from about 2000 to 2400 feet, separated from one another by deep glens. The deepest and shortest of these is the narrow pass between Arrochar and Tarbet. Here the two lochs nearly meet, and the neck of land between them, $1\frac{3}{4}$ miles in length, is at the highest point only about 160 feet above sea-level. This remarkable gap across the high plateau is not occupied by any stream of importance, and if it is due to erosion it must have been excavated by some stream which was long ago cut off or dried up. It may be mentioned that two basalt dykes have been traced along its course running in an ENE. direction from Argyllshire to the Loch Lomond ridge. These dykes have perhaps decomposed more easily than the metamorphic rock, and have no doubt been instrumental in directing the course of the original stream and giving the pass a more northerly trend than the other glens leading to Loch Lomond, which we shall now notice.

Four and a half miles below Tarbet we come to Inverbeg, at the mouth of Glen Douglas, where the Douglas Water enters Loch Lomond at a small alluvial delta projecting from the foot of the steep mountain slope into the deep water, The Douglas Water has a comparatively straight course of four and a half miles, and Glen Douglas, which forms the second gap through the mountains, is only five miles in length between Loch Lomond and Loch Long. The

highest point in the glen is about 500 feet above sea-level, and only half a mile from Loch Long. The surrounding mountains are over 2000 feet in height, and the glen is therefore cut right through them to a depth of over 1500 feet. The watershed is along the ridge of Creagan Hill, and on the actual slopes of Loch Long, and the tributaries of the Douglas first flow down the western sides of the mountains towards that loch. But, here urged by some mysterious force, they turn eastwards towards Loch Lomond through the deep cut of Glen Douglas, although their course is thus lengthened by four miles. The West Highland Railway along Loch Long approximately follows the watershed at this place, and the observant passenger can get a short glimpse of how the streams run from the Loch Long glen right down Glen Douglas to Loch Lomond.

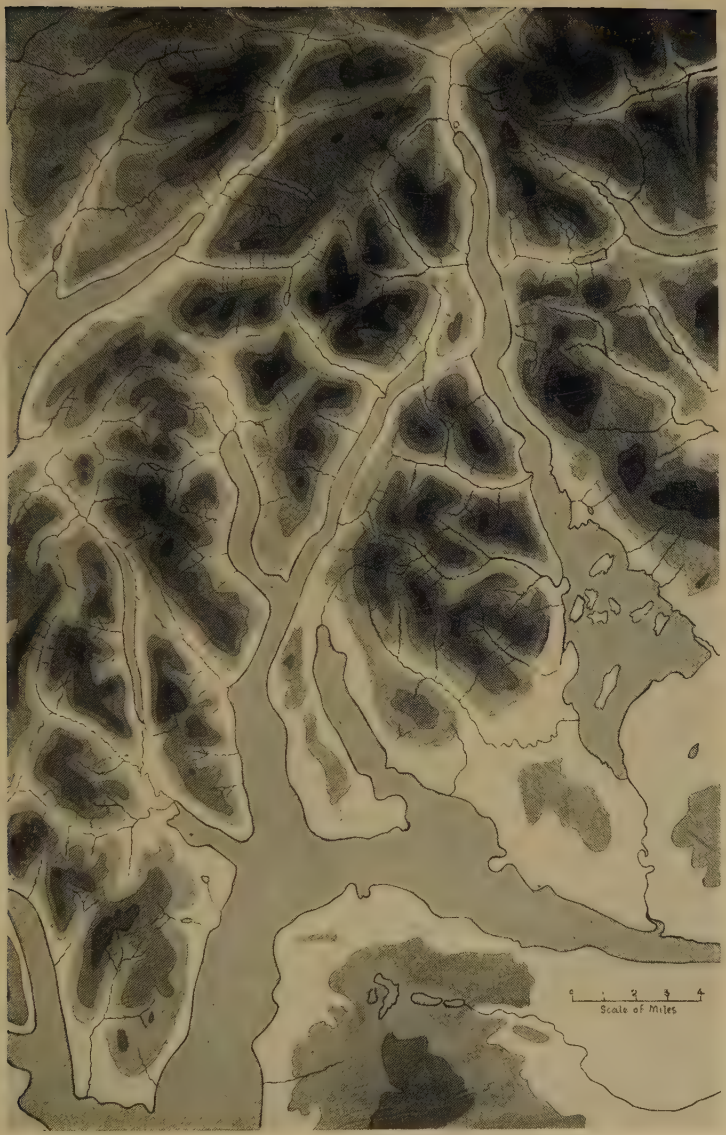
Glen Luss, about three miles further south, is likewise trenched right across the plateau, but not to such a depth as Glen Douglas. The Luss Water from mouth to source has a course of about six miles as the crow flies, and its head tributaries rise about a mile and a half from Loch Long.

Glen Fruin again has the same south-easterly trend, but is a longer and wider valley. The Fruin Water rises about a mile from Garelochhead, and two miles from Loch Long, and reaches Loch Lomond at Arden after a course of ten miles.

The next valley to the south of Glen Fruin is the submerged trough of the Gareloch, once doubtless the line of a river that ran in the same direction. To this we shall return again.

The Dumbartonshire glens thus agree in ending in a water-parting close to the shore of Loch Long, and in having streams which all flow in an easterly or south-easterly direction in deep and well-defined courses through the plateau.

If we now cross Loch Long into "Argyle's Bowling Green" and the adjacent rugged mountainous coast of Argyllshire, we find the same physical peculiarities in evidence. The water-parting hugs the east shore of Loch Fyne, and the glens are trenched through the



LOCH LOMOND, LOCH LONG AND FIRTH OF CLYDE SHOWING THE VALLEY SYSTEM.

The areas left white are under 500 feet above sea-level, and each gradation of shading represents a rise of 500 feet.

To face page 58.

heart of the mountains in such a way that the streams flow away south-eastwards towards Loch Long. With the exception of the Kinglas Water, no stream of any volume is seen to run in a westerly direction to the Loch Fyne Valley. The most conspicuous case is that of the River Cur, which drains the country south of Loch Goil, and enters the Clyde at the head of the Holy Loch. This stream, after following a steep mountain course to the south-west for four miles, reaches a point near Strachur less than 150 feet above sea-level, and only half a mile from the shore of the loch. Urged eastward by the same apparently inscrutable principle, instead of flowing on to Loch Fyne and reaching the sea by the shortest path, it wheels sharply round to the left, and turning its back on the coast, plunges into the deep defile of Loch Eck, a glen which joins the Loch Long Valley at the mouth of the Holy Loch, fourteen miles from the turning-point at Strachur. This defile is very narrow, and is excavated almost to sea-level through a mountain plateau over 2000 feet in height. The level of Loch Eck is only 67 feet above the sea, and the bed of the original valley, now partly filled by alluvium, is no doubt considerably below sea-level for a long distance up the defile.

Loch Goil occupies the next cut through the plateau north of the Holy Loch. The valley ends in Hell's Glen, a deep defile whose highest point is about a mile and a half from Loch Fyne and a little over 700 feet above sea-level. This trench is not so deep or long as that of Loch Eck, but it has one notable peculiarity. It abuts on Loch Long in such a way that its axis is in line with that of the Gareloch, which suggests that the two were originally one valley.

Glen Croe, the northmost of the side glens on Loch Long, also forms part of a deep defile through the ridge to Loch Fyne. But in this case there is another equally large stream at the west end—the Kinglas Water—and the water-parting at Rest-and-be-thankful is midway between the two sea lochs. Glen Croe is very deep and

narrow, and skirts the south side of Ben Arthur (the Cobbler), which is nearly 2900 feet in height. The mountains at the head of Loch Long and Loch Fyne form the highest ground on the west side of Loch Lomond, and Ben Ime, the tallest of the group, is 3318 feet in height. The rainfall on their crests is large, and the streams where the gradient is high have considerable erosive power.

Loch Long ends at Arrochar in Glen Loin, which runs northward for three miles, and if its line of axis were produced a mile or two further it would strike straight into Loch Lomond. But here another circumstance falls to be noted. Glen Loin is crossed at right angles by the Inveruglas Water, which cuts off the northern extremity of the triangular plateau and discharges into Loch Lomond. This stream rises in the wild granitic plateau beyond Loch Sloy, and runs south-eastwards for three miles in a deep V-shaped glen between Ben Vorlich and Ben Vane. Loch Sloy the former habitation of the "wild Macfarlanes' plaided clan," occupies a mile and a quarter of the glen. It is 812 feet above sea-level and 2280 feet below the crest of Ben Vorlich. The lochan is a lonely and desolate streak of water overhung by barren mountains and studded round with the moraine heaps of the old glaciers that once covered the plateau, and radiated out into the glens. They finally melted away long before the wild clansmen likewise radiated into the low country, gradually melted away, and at last disappeared from the inhospitable region. This little corner is mentioned, as it will be found to illustrate a point in the process of development of the river system to which reference will again be made. (See sketch at p. 120.)

On the east side of Loch Lomond, exactly opposite the line of the Inveruglas Glen, the Arklet Water enters the valley at Inversnaid. Glen Arklet is a little over four miles long from Inversnaid to Loch Katrine, and forms the only deep gap through the Ben Lomond ridge. Loch Arklet is 463 feet above sea-level, and the ground to the north of it is more than 2100 feet high. The gap is thus cut some 1600 feet down into the ridge, and this, like the other facts

which have been cited, is, as we shall see, a point of some significance in the topographical history of the district.

When we come over to the south side of the Firth of Clyde above Gourock we find the same eastward trend of the principal tributaries and glens, which generally run more or less in the opposite direction to that of the main river. The Gryfe Water, which rises at the head of Strath Gryfe, a little more than two miles south of the Clyde at Port-Glasgow, instead of flowing northwards down the steep slope by the shortest route to the sea, takes a long eastward journey in an independent glen of its own to join the River Cart, which enters the Clyde near Renfrew, about twelve miles further up.

The Black Cart Water, issuing from Castle Semple Loch, flows north-eastwards for eleven miles, along a deep and well-marked gap used by the Glasgow and South-Western Railway, which runs straight through the Renfrew hills from Johnstone to Kilbirnie and Dalry. At the watershed the bottom of the gap is only about 200 feet above sea-level, while the hills on the north-west side of the glen rise to heights of over 1000, and those to the south-east to over 800 feet.

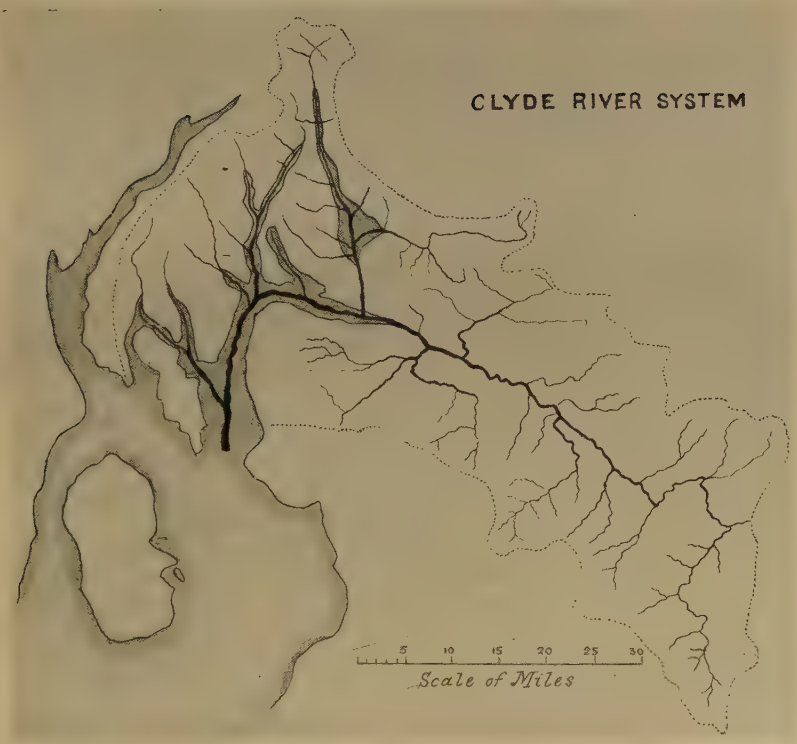
Four or five miles further east the ridge is crossed by another smaller trench running also north-eastwards past Neilston and Barrhead, 300 to 400 feet deeper than the surrounding country. This is occupied by the Cowden Burn, a small tributary of the White Cart. The line of this gap, if produced, would cross the Clyde at Rutherglen and make an acute angle with the main river below the confluence, instead of the obtuse angle that would be natural in a normal tributary.

If we now visit the country between the Forth and Clyde we again find in the Campsie ridge evidences of an older and comparatively disused river system. The first feature in the district is the well-marked narrow trench that crosses the country in a straight line between Clydebank, Kilsyth, and Larbert. This channel is occupied by two insignificant streams, the Kelvin flowing west towards Glasgow, and the Bonny Water, a tributary of the Carron, which runs

eastwards and enters the Forth at Grangemouth. These two streams rise at a place called Kelvinhead, two miles east of Kilsyth, where the height of the valley bed and the water-parting of the country is only about 150 feet above mean sea-level. This remarkable gap is used for the Forth and Clyde barge canal, and is one of the routes suggested for the proposed ship canal across Scotland. It is not produced by faulting of the strata, and is evidently the work of an ancient and swift river with great erosive power, well able to excavate a deep gorge in hard rock, which the puny streams that now wimple gently along the hollow could never have done.

If we prolong the line of this valley to the west, it is found to run exactly in line with the gap we have just noticed in the Renfrew Hills at Castle Semple.

The Campsie and Kilpatrick Hills, which form the south-western continuation of the long Sidlaw and Ochil range, consist of great flattish terraces or beds of hard volcanic rock on a foundation of softer sedimentary strata. These separate plateaus evidently form the detached parts of what was once a single long flat-topped ridge or table-land stretching away northwards from what is now the Kelvin and Bonny Valley to the base of the Highland mountains. The plateau has been worn away by the Forth on the north, and bisected in the centre by Strathblane, a deep, broad glen that runs south-eastwards almost exactly in a straight line with the eastern side of Loch Lomond. Strathblane extends southwards past the village of Campsie and Lennoxtown and joins the Kelvin Valley west of Kilsyth. The watershed is at Ballagan, near Campsie, and the western end of the glen forms the course of the Blane, a small stream running westwards into the Endrick, which enters the east corner of Loch Lomond at Buchanan Castle. The height of the watershed is a little over 250 feet at Campsie, and, as the adjacent Strathblane Hills are over 1600 feet in height, a breach more than 1300 feet in depth has been cut in the plateau long ago by some river of more importance than any of the existing local burns. The



THE CLYDE RIVER SYSTEM.

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excavation of this breach in the plateau has been originally facilitated by a large fault which runs obliquely across it and has produced a line of weakness like that in the Forth Valley at Stirling.[1]

Now it is possible, I think, to fit these data together, and to construct the general framework of the story they have to tell. An inspection of the accompanying map of the Clyde river system shows it to be altogether abnormal and irregular, quite unlike the plan of a consequent stream following a definite course to the sea.

In the part of the country under consideration the principal rivers and valleys are thus seen to follow a general easterly, south-, or north-easterly course, but with one notable exception—the Clyde, which flows in exactly the opposite direction. The Clyde is apparently an obsequent river above Gourock, and the Glasgow district is evidently the site of an ancient battlefield between two contending rivers, such as A and B in the diagram, where the Clyde has, like A, become the victor, and brought the long struggle to an end by decapitating the Forth, and greatly diminishing its former grandeur. The Clyde has been the Highland robber, and the Forth the Lowland sufferer, by this ancient invasion from the wild West. A large part of the original territory of the Forth, some 1200 square miles in extent, has apparently been cut off, and the water drawn aside from its ancient channels.

When first I suggested in 1886 that the Clyde and its tributaries originally ran into the Forth, some geologists in the West were offended at the idea that the Clyde was a usurper and the predatory habits that once characterised Dumbarton and Argyllshire dated back to such a remote antiquity. But a quarter of a century has not altered my opinion, and, indeed, the study of other river systems has only served to strengthen it. To make a long story short, the appended sketch-map indicates what I believe may have been the

[1] An interesting account of the changes in the local drainage system of the Campsie plateau is given by Mr. E. B. Bailey in the *Geological Survey Memoir of the Glasgow District*, 1911, pp. 198-201.

general outline of the river system of the Forth, if not at the very beginning, certainly at an early stage in its career, when the valleys were several hundreds of feet shallower than they are in our time.[1]

The excavation of the original valleys dates from a considerably later time than the Miocene age, but, as we have seen, they were in existence long before the Glacial period. In surveying the high ground at the head of Loch Lomond I once traced a large basalt dyke right across the Loch Sloy defile and over Ben Vorlich, at a height of 2950 feet. Now this dyke, which is only one of many in the district, was injected from below into a fissure which ran eastwards across the country towards Loch Katrine, at a time when the deep valleys had no existence, otherwise the molten lava would have escaped at the lowest point, flooded the valley beds, and never found its way up to the top of the plateau. The glens have thus, like teeth cut in a saw, been notched out of the basalt veins since the Miocene age, when volcanoes were numerous in the western isles, and multitudes of dykes were injected into cracks in the Highland plateau. The Ice age intervened after the rivers had excavated their valleys, and although, as we shall see, the glaciers produced important changes, they were not instrumental in producing the valleys themselves.

The ancient Forth and Clyde watershed at the period in question was evidently along a range of mountains west of Loch Long. This range formed the seaward boundary of the north-west of Europe, and must have been much higher and more imposing than the half-submerged fragments that now remain. The western sea lochs were then river valleys, and the Firth of Forth the bed of a great river flowing far beyond the mouth of the present estuary. The great size

[1] My old friends and former colleagues, Messrs. Peach and Horne, in their account of the Scottish Lakes in the *Report of the Bathymetrical Survey* by Sir John Murray and W. L. Pullar (1910), refer at pp. 465-6 to the origin of the Forth and Clyde valleys, and offer a somewhat different explanation of their early history. No doubt there is room for discussion, but I still venture to think my old riverbeds will hold water, if not at every loop, at least in most of the deepest pools.

MAP SHOWING THE SUPPOSED ANCIENT RIVER SYSTEM OF THE FORTH BEFORE THE CLYDE HAD BROKEN THROUGH THE ORIGINAL WATERSHED.

To face page 64.

of the Firth of Forth, which forms the most conspicuous notch in the coast between the Moray Firth and the Thames, shows how large the ancient river must have been at one time.

But here the reader may well ask: "How do you know that the long trough of the Firth of Forth was not really produced by a bending down or subsidence of the land?" To this very reasonable objection I reply, "See how the Carron, Avon, Almond, Water of Leith and other main tributaries run in an easterly or north-easterly direction, and not straight northwards by the shortest route to the sea. Had there been a sinking down of the land to produce the main valley, the water would have run down the declivity like rain on a roof perpendicularly to the contour lines and not at an oblique angle or nearly parallel to them." No, the trend of the side valleys is clearly the result of some widespread original cause that has stamped permanently on the face of the country the general pattern of its first river system.

There was one important difference between the eastward and the westward flowing waters. Those flowing west had not nearly so far to go as those flowing eastwards, to their ultimate oceanic destination. The consequence was that the latter, flowing at a lower gradient, had probably less velocity and therefore less erosive power than the former. In this case, unlike that illustrated in the diagram, it was thus not the greater hardness of the bedrock but the lower gradient, which put the Forth at a disadvantage in the struggle for supremacy with the Clyde. Then again most of the rain clouds which come from the Atlantic would condense on the part of the range next the coast, and so the westward flowing streams would receive at their sources more water than those in the drier eastern region.

The ancient Clyde and its tributaries would thus have most erosive power, and be best able, when fairly started, to eat back into the borders of the plateau originally in the Forth domain, and when once the invader became strengthened and the defender weakened by these conquests, the process of acquisition would become ever easier.

We are not now concerned with the part of the Clyde Valley below Wemyss Bay. Let us suppose a large river running southwards off the plateau towards the Irish Sea, with its head tributaries in Loch Striven, the Kyles of Bute, Loch Fyne, and the Clyde Valley below Dunoon. Each of these, well replenished by the heavy rainfall, like Niagara on a small scale, ate its way back into the mountains, slowly at first, no doubt. The eastmost branch gradually managed to work back and northwards till it crossed and penetrated the soft sandstone on the watershed at Dunoon and tapped the headwaters of the eastward-flowing tributary of the Forth, now the upper part of the Firth of Clyde. The bed of the eastward-flowing river, with its long seaward course, was no doubt situated at a higher level than that of the invading river, and probably occupied a comparatively flat valley. When once it was tapped at the head the whole drainage of the Loch Eck Valley was diverted southwards into the thriving Clyde. The additional volume of water increased the flow of the river, and this tributary became more important than its next neighbour at Loch Striven, and went on deepening its course and extending its territory. To make the subject as clear as possible, the accompanying imaginary bird's eye view is intended to show what may have been the general appearance of the ancient Forth and Clyde Valley at this stage, when the Clyde was about to break through into the Forth basin near what is now Dunoon.

The original slope, while it determined the general direction of flow, was not the only factor in shaping the trend of the river courses. The rocks might be so inclined, and the land surface so grained, that the work of excavation became much easier in some directions than others. If we try to draw the point of a nail obliquely across the grain of a fir board, the moving point will describe a series of zig-zags —the result of the struggle between the draughtsman's hand and the lateral resistance of the fibre of the wood to a point drawn obliquely across it, and this will illustrate the operation of the forces determining the minor changes in the directions of the valleys.

BIRD'S-EYE VIEW NORTH-EASTWARDS FROM THE SUPPOSED ANCIENT WATERSHED, BEFORE THE CLYDE HAD BROKEN THROUGH INTO THE FORTH BASIN.

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In the several parts of the district there is evidence of such a struggle having taken place in the early days of the river valleys. The water was trying to flow south-eastwards, and the strike or grain of the plateau, particularly in the Cowal area, was towards the SW. or SSW. The tendency was therefore to deflect the stream towards the south. This is best seen in the Cur Valley, which has all the appearance of having originally extended in a perfectly straight line from Strachur to Ardentinny at the mouth of Glen Finart. Glen Finart ends in a wind-gap at the bend of Loch Eck, and the lower part of Loch Long is probably the south-eastern prolongation of the original valley. The Holy Loch and Glen Massan may have been another parallel valley at first, but owing to the grain of the rock between these valleys, the Cur found it easier to abandon its original track and bend in a more southerly direction towards Glen Massan. This geological feature, combined with the prevailing tendency of subsequent streams to run southwards, appears to have made the recession of the falls in all cases greatest towards the north, and all the invaders accordingly traversed the Forth and its tributaries in that direction. The lower part of Lock Eck is thus probably on the course of an original tributary of the River Massan which ate its way northwards and stole the headwaters of the Finart at an early stage. The decapitated Finart was thus unable to do much digging, and the Loch Eck defile became the principal glen.

The advancing Clyde next pushed out an arm northwards and succeeded in cutting off the upper part of the Loch Goil and Gareloch river, and, following the line of one of the numerous joints or weak places on the site of Loch Long, it apparently cut off a small piece of the head of Glen Douglas, which remains in Coilessan Glen, and finally reached Ben Arthur and diverted the Glen Croe Water into the lower channel, drying up the gap leading to the Loch Lomond Valley at Tarbet.

I need scarcely say that it is not easy, particularly for those who have not made a special study of such matters, to picture to the mind

how all this has taken place, nor to realise the vastness of the time these operations involved, but all the circumstances seem to show that this has undoubtedly been the general course of events in the evolution of the valley system of the district.

The last stream to be cut off was the Glen Croe Water, and this is no doubt the reason why the gap at Arrochar is the deepest that crosses the Dumbartonshire Highlands. The River Croe had more time to work down its bed before it was decapitated, or rather curtailed, and had therefore excavated its glen to a greater depth than the other streams. When the River Cur was curtailed its glen was no deeper than the top of the wind-gap at Whistlefield above Garelochhead, 320 feet at least above the present sea-level, but the bottom of the old Glen Croe between Arrochar and Tarbet only rises to a height of 160 feet. Since it was dried up it has probably not been reduced much in height, as it has no important streams to wear it down, and the glaciers that deepened the other glens flowed across and not along its axis.

Although the Loch Long glen is nearly all submerged, it is still possible to trace the same process of erosion going on in Glen Loin, its northern prolongation beyond Arrochar, and this helps to illustrate the method on which these glens seem to have been originally formed. The head of the valley for a mile above Arrochar is filled up with the alluvium of the stream which, instead of eroding, is here depositing a delta at sea-level. Could the land be lifted and the valley again dried up, a waterfall would at once be produced in Glen Loin which would work its way up the glen towards Loch Sloy. But out of Loch Sloy there is another stream, the Inveruglas Water, running eastwards across the course of Glen Loin into Loch Lomond. There will be a competition between these two streams as to which of them can deepen its bed fastest. But in this connection another circumstance must be noted. The surface of Loch Lomond is at present about 23 feet above sea-level, and so long as it thus remains above the level of Loch Long, the streams running into the sea loch will have the advantage of so much more of a fall over those flowing to the inland basin. In course

of time the Inveruglas Glen will be worn down nearly to the level of Loch Lomond, but deeper it cannot go unless Loch Lomond also subsides. At the same time the Loin Water will continue to lower its glen, and if, as we have supposed, the land were to be upheaved so as to dry up Loch Long, but not Loch Lomond, which is an inland lake, the work will be hastened and the Loin will at last break through the watershed and draw off the Inveruglas to the south. The Long Valley will thus be extended for three miles, and the last mile of the Inveruglas Glen will be dried up, leaving a deep, short wind-gap similar to the one at Arrochar and Tarbet. The Loin, thus reinforced by the much larger volume of the stream issuing from Loch Sloy, will receive a fresh lease of life and will go on eating back its glen into the mountains, and finally draining the little lochan entirely away. Thus in the remote future Loch Long might, especially if a slight submergence were to occur, be found to have pushed its way far back through the defile between Ben Vorlich and Ben Vane into the plateau west of Ardlui.

In all this district the massive metamorphic schists are intersected in different directions by great vertical master joints, and no doubt the very straight course of Loch Long is partly due to these lines of cleavage running parallel to the valley. The steep mountain slopes are often covered with immense blocks and heaps of rock that have slipped down in large slices, and at some places, particularly in the gap at Tarbet, deep fissures can be seen high up on its southern slopes which mark the lines of incipient landslips. Stones dropped into some of these rents can be heard rattling a long way down into the mountain side, and some day, when perhaps there is an abnormal snow or rainfall, pieces of the loosened mountain side will move downwards and no doubt alarm the inhabitants by the exhibition of a geological phenomenon that happily is not now very common on a large scale in the district.

While this was probably something like the early history of the valley, the other tributaries of the pushful Clyde were not idle. It

must be mentioned that the rocks at the turn of the estuary above Dunoon are soft Carboniferous or Old Red Sandstone strata much more easily eroded than the tough old Highland schists further north, and the high ground on the south side is made up of hard volcanic rocks, the continuation of the Campsie and Kilpatrick range. Between these two hard tracts the Clyde has dug its channel. When the first breach had been made into the old Forth Valley between Holy Loch and Gourock, the head of the stream flowing east was diverted to the south, and very little water was left to feed the Forth from this source. The next part to be tapped was the water in the previously decapitated Gareloch Valley, and there may have been a waterfall where it entered the Clyde near Greenock. As the process went on the whole of the upper reach of the ancient Forth became in time obsequent, and it did not give much further trouble to the Clyde to draw off the remainder of the old river as far east as Kilsyth, through the outlet at Gourock. The sedimentary rocks in that district are more or less easily eroded, and the deep breaches through the harder volcanic ridge of the Campsie, Kilpatrick, and Renfrew hills, had been already cut out by the older river. All this work, it must be remembered, was done at the time when the river beds were above the level of the gap at Whistlefield, at least 320 feet higher than at present, and the firths and lochs had no existence. The general subsidence of Scotland at the Glacial period finally submerged these old valleys and converted the deepest of them into arms of the sea.

If the original Clyde, on this hypothesis, entered the Forth by the col (or watershed) at Kelvinhead, which remains still about 160 feet above sea-level, it follows that all the river basin to the west must have been then at a higher level than the col.[1] Supposing for the sake of argument we disregard the probable additional height of the

[1] This is the height of the surface of the ground only, but the true rock bed of the col is less than this. Recent borings in the valley have proved that there is a covering of 60 feet of soil and drift over the rock a short distance west of Kelvinhead, and thus the height of the rock bed of the ancient channel may have been less than 100 feet here.

whole ancient land surface above the sea, and take the level of the Kelvinhead watershed when last occupied by the old river at 160 feet above ordnance datum. If the river had a fall of say 4 feet per mile, which is a moderate gradient, the distance from Kelvinhead to Gourock being 33 miles, the whole fall would be 132 feet and the height of the valley at Gourock 292 feet above its present level. At this gradient the river bed would be at Whistlefield, which is 9 miles further on, 36 feet higher, or 328 feet above sea-level. The actual height happens to be 320 feet at that spot, and this helps to show roughly how much higher the bed of what is now the Clyde must have been at the time of which we are now speaking. No doubt the absolute height above the sea was far more than this, as the whole country must have been far above the present sea-level, but that does not affect the present argument.

If we were to fill up the Clyde at Dunoon by a dam only 200 feet high, and make a smaller barrier at Castle Semple Loch, the Clyde and all its tributaries would submerge the Glasgow district again and overflow into the Forth by way of the Kelvin Valley.

The Loch Lomond Valley appears to have a somewhat different history from that of Loch Long. It is, I believe, in the main an old consequent valley, and the Ben Lomond ridge marks part of an original water-parting between two tributaries of the Forth. The southern broad part of the loch, with its beautiful archipelago of low islands, is entirely excavated out of soft sandstone, and the great fault which forms the junction line between the metamorphic and sedimentary rocks runs across it in a NE. direction past the north side of Inchlonaig.

As already noted, the east side of Loch Lomond as far north as Tarbet trends nearly in a straight line, striking south-eastwards for the Strathblane gap in the Campsie plateau, and this seems to be the line of the old consequent river valley. Above Tarbet, however, the glen narrows and runs almost due northwards. At this slight

bend the ancient mouth of Glen Croe comes in, and here it seems to me the original valley ended and split into two smaller glens. Glen Croe, whose history we have already considered, was the larger, and the smaller one ran straight northwards for about two miles, ending originally in a corrie below Inversnaid and Upper Inveruglas.

This may appear at first sight a curious conclusion, but it seems to be warranted by the following evidence:

At Inversnaid, exactly opposite Upper Inveruglas, the Ben Lomond ridge, as we have seen, is notched by the deep gap of Glen Arklet, which runs through to Loch Arklet, and is at its highest point only 463 feet above sea-level. This is the only pass through to Loch Katrine, and is cut across a ridge of mountains more than 2000 feet in height. It is thus some 1600 feet deep, and lies exactly in the line of the Inveruglas Glen, which is also of great depth. Glen Arklet is manifestly the eastern continuation of that valley, and the two were connected at a time when the Loch Lomond river was 500 feet higher than at present. The panoramic sketch from the top of Ben Vorlich shows the Loch Katrine Valley, Loch Arklet and Glen Arklet crossing the Ben Lomond ridge at Inversnaid.

The ancient outlet of Loch Sloy was thus in its lower reaches a straight valley about six miles long which apparently joined Strath Gartney on the site of what afterwards became Loch Katrine, or perhaps its waters overflowed into the valley of Loch Chon and Loch Ard and broke through the Menteith Hills at Aberfoyle in the Forth Valley.

If this be so, it is clear the Loch Lomond stream did a little stealing like its neighbour of Loch Long. The tributary we have supposed to run southwards towards Tarbet seems to have followed the prevailing fashion, eaten its way north and tapped the eastward-flowing Arklet-Inveruglas Water, no doubt occupying a more elevated glen, as the Loch Long river was doing a few miles away. The Inveruglas stream was drawn off and a dry wind-gap left through the

VIEW EASTWARD FROM BEN VORLICH (3,092 feet).

Showing Loch Lomond, Loch Katrine, Loch Arklet and the obsequent Arklet Valley crossing the Ben Lomond Ridge at Inversnaid.

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Ben Lomond ridge, which in course of time formed the bed of the obsequent little River Arklet well known to tourists at the falls of Inversnaid. The new dam of the Glasgow waterworks across the glen above Inversnaid will have the effect of sending the water eastwards into Loch Katrine, and changing the Arklet from an obsequent to a consequent river once more.

There still remains for explanation the northward extension of Loch Lomond, and here I admit the evidence is not very clear. It looks to me as if the Clyde by this time had drawn off the lower part of the Loch Lomond river, and there was thus a much greater fall towards the south than to the east. In this way the southward flowing tributaries of the Clyde would be eating their way backwards into the plateau much faster than the headwaters of the Forth. There is no clear evidence of a line of fault, but there may well have been a straight series of joints or a line of weakness at this place which produced two original glens in the line of the Loch Lomond Valley, and the ancient Inveruglas Water may have been joined on the north by a large stream on this line opposite the very place where it was being tapped from the south. When the barrier was cut through, the northern tributary thus ran straight on down the line of the crack, which in time became greatly deepened and widened with the additional volume of the confluent waters from the high plateau to the north and west, and was finally still further excavated by glacier action to a depth of more than 600 feet below the present sea-level.

The river, whose headwaters thus probably at first ran from the Ben Ime and Loch Sloy plateau, eastwards towards the Trossachs, would form an important feeder to the great tributary of the Forth that originally excavated the glens of Loch Katrine or Loch Chon, which are now occupied by far smaller streams than their size seems to warrant.

The Douglas and Luss waters were, no doubt, branches of the original Loch Lomond river. The Fruin and Finlas glens probably mark the sites of two branches of another considerable stream which

ran south-eastwards through the gap at Alexandria, now occupied by the River Leven. All these points can best be followed by reference to the appended map of the supposed old river system.

After all these depredations the south-western branch of the Forth shrank up and became obsequent from Kilsyth westwards, and the northern branch, above the confluence at Grangemouth, became henceforth the main trunk of the river.

The Forth crossed the volcanic ridge of the Campsies and Ochils at Stirling, having, no doubt, sought out its weakest place, where the rocks were not only dislocated by several great fractures, but the hard whinstone beds of the two ranges had thinned away at their outcrop to a narrow neck through which the river had no difficulty in selecting and clearing out a passage. Above Stirling the rocks in the Vale of Menteith are principally Old Red and Carboniferous sediments and the degradation of these was regulated by the rate at which the river was able to deepen its gorge in the harder whinstone barrier between Stirling Castle and the Abbey Craig, at the foot of the Ochils.

The lowering of the Loch Lomond Valley went on at the same time. In the gap at Balfron there are traces of a channel between that old branch of the Forth and the present river, before the Clyde had completely won in the race of degradation, deepened its bed, and sucked away the last vestiges of the original tributary. The Teith, flowing from Loch Katrine and Loch Lubnaig, is an old tributary from the north, but the Allan Water, like the Devon, is apparently a more modern and partly an obsequent stream, belonging to a later period. Both the Devon and the Allan enter in the wrong direction and cannot be considered as part of the original river system.

It is noteworthy that the Forth below Stirling has no large tributaries from the north. On the south, however, besides the Carron, three normal rivers enter the Firth, and run north-eastwards in old valleys nearly parallel to the Kelvin-Bonny glen. The River

Avon, on the west boundary of Linlithgowshire, although it now turns sharply to the west at Linlithgow Bridge, no doubt once continued its north-eastern course to the main river below Blackness. The ancient valley has been deeply trenched across the hard volcanic ridge, which must have once formed a single range extending continuously through West Lothian from the site of Bathgate to what is now Bo'ness on the shore of the estuary. The hollow in which the romantic old Linlithgow palace and loch nestle in picturesque serenity was part of the original Avon Valley before the Ice Age, the last three miles of the present glen above Inveravon being a comparatively recent excavation. The orographical map of the buried river valleys will make this point clear.

The Almond, which bounds the county on the east, is also apparently another old consequent stream. It too has slightly changed its course at the mouth. The old glen ran under Dalmeny House, and the gorge between Cramond and Craigiehall was excavated after the Ice Age. At that time the whole country was first swept by a great glacier or continental ice sheet, and when the ice melted the land was left so deeply buried under drift and clay that the rivers were often unable to recognise their old valleys, and had to start afresh to cut out new beds through the solid rock at the places where the ancient tracks had been lost and could not be recovered. The Almond, and its principal tributary the Breich, run for twenty-two miles in an almost perfectly straight course towards the north-east. The original Almond Valley may have been continued at an early stage south-westwards across the line of the Clyde near Wishaw and Shotts to Strathavon, and been decapitated like the higher tributaries of the Forth, but that part of the Almond watershed is over 700 feet above sea-level, and the traces of the ancient valley system are somewhat faint in this district.

The Water of Leith and the North Esk in Midlothian both flow in the same general direction, one on each side of the Pentland ridge.

Those rivers of the Lothians have neither robbed their neighbours nor been much disturbed themselves in the course of their comparatively even history.[1] The rainfall being here much lighter than in the west, and the country flatter, their erosive power has been less than that of the higher tributaries of the Forth, and there has thus been little of eventful episode to record in their career.

But the Clyde did not rest content with robbing the Forth of so much territory. It worked its way as a subsequent river south-eastwards by Lanark, and appears to have ended by also invading the Tweed basin and drawing off some of the headwaters of that old consequent river at Biggar. But this is a question which does not concern the present investigation. The reason why the western river was able to wear down its valleys faster than the eastern streams is no doubt that the fall was greater to the west, and the rainfall was also much heavier next the Atlantic seaboard than elsewhere. The land surface was a vast sloping plateau culminating in high mountains with a steep fall towards the Atlantic Ocean, and a long gentle inclination eastwards towards the mainland of Europe, of which Scotland was then but the remote north-western corner.

Now it is quite possible that some serious reader of these pages may be inclined to smile at this hypothesis as a scientific dreamer's fanciful and far-fetched story, incapable of verification at this time of day. Of course, the writer is not a kind of super-Methuselah who personally witnessed the ancient battle of the Forth and Clyde, and well it is so, for had he been, it is certain he should never have survived the Ice Age and been here to tell the tale to this intelligent generation. However that may be, in defence of the argument it may be mentioned that the story is not absolutely singular and unsubstantiated from other quarters, and for the benefit

[1] In the *Geological Survey Memoir on the Neighbourhood of Edinburgh*, 1910, p. 326, Dr. C. B. Crampton and Mr. L. W. Hinxman give an interesting example of a small depredation by the South Esk, which has captured at Borthwick the North and South Middleton Burns, two streams that originally flowed into the river Tyne.

M. SAN VALENTIN
C. NEVADO
R. Deseado
R. Chacabuco
M. ARENALES
R. Baker
M. COCHRANE
R. Seco
M. BAÑEZ
R. Olaï
R. Pascua
R. Mayer
M. HUMBOLDT
R. Belgrano
CHALTEN
R. Shehuen
R. Santa Cruz
ATLANTIC
OCEAN
SNOWFIELD
PART OF PATAGONIA
SHOWING CHANGES OF WATERSHED
Present Watershed
Probable Ancient Watershed
Scale of Miles
0
25
50
100

of any such honest doubter the following evidence may now be considered.

Patagonia is a remote continental promontory between two great oceans with a physical configuration analogous in several respects to that of Scotland. The western coast forms the end of the lofty volcanic ridge of the Andes, which, like the West Highlands of Scotland, rises steeply from the ocean and is intersected with deep fiords and inlets. The high ground is covered with a sheet of ice and snow, and many of the glaciers come down to sea-level. The snow-clad plateau reaches to a height of over 4,000 feet, and the mists and rain that almost perpetually prevail have greatly hindered the complete exploration of the inhospitable region. The eastern part of Patagonia—the dry and desert-like plain of the Pampas—slopes gently from the Andine plateau to the Atlantic coast.

Mr. P. D. Quensel, a member of the Swedish Magellanian expedition of 1907-9, in an interesting paper on the "Influence of the Ice Age on the Continental Watershed of Patagonia,"[1] shows how the original continental line of watershed of that part of South America has been generally shifted eastwards in recent geological times, in several instances as much as forty miles. Most of the heavy rainfall formerly escaped eastwards across the Pampas to the Atlantic through large valleys now almost dry, some of which are over 200 miles in length. "On the whole," he says, "most of the rivers are out of proportion to the great valleys they follow, and in several places the continent is intersected by a well-defined and broad valley without even a rivulet following the old watercourse."

The ice sheet that still covers a large part of the Andine plateau has shrunk back in recent times, leaving exposed a series of large lakes near the watershed and a fringe of morainic deposits that extends eastwards for many miles beyond its present border, and at several places forms the present low continental divide. Quensel attributes these old river valleys of the Pampas to the melting of the

[1] Published in the *Bulletin* of the Geological Institution of Upsala for 1908-9, pp. 60-92.

ice that once completely filled their upper reaches and blocked up their supposed western outlets while it prevailed. But he quotes other observers who offer different explanations of the change in the drainage system of the region, and refers to some who attribute the transandine valleys to gigantic faults and tectonic disturbances of the strata.

Without entering fully into the interesting discussion, it seems to me perfectly clear from the maps and evidence of different explorers that the great lakes in the watershed of Patagonia are merely the upper ends of the old river valleys that cross the continent from the original watershed to the Atlantic shore. These have been locally deepened, like our own lochs, by the glaciers, when the climate was colder, or perhaps when the land was higher than it is in our day.

The islands and fiords on the Pacific coast show that there has been, as in Scotland, a recent submergence of a land surface much cut up by tortuous river valleys, and therefore the land must have been higher and consequently colder before it settled down to its present position. The old valleys were in existence, it cannot be doubted, before the extension of the ice in this region, and if the maps are to be believed, their tortuous courses show that they were produced, not by gigantic faults and fissures, as some writers would have us suppose, but by the ordinary process of river erosion that we have seen at work in other places.

The watershed may have been modified by the glaciers which also excavated the lakes, but the main reason why it has been shifted eastwards is perfectly plain to me. The old valleys have been dried up at the source, and the lakes that once discharged by long channels with low gradients to the Atlantic have been tapped by swift streams with many waterfalls and short steep courses leading to the Pacific. These have succeeded in time in eating their way backward through the plateau, and decapitating the old consequent rivers of the Pampas. The Baker and Pascua rivers, for example, are seen

on the map to have each an abnormal obsequent course with tributaries entering in the wrong direction and pointing more or less upstream like the Gryfe Water in the valley of the Clyde.

We have thus before us distinct and independent evidence of a river system that has been greatly modified in comparatively recent times by similar natural processes to those that altered the Scottish river system in a remoter age.

OROGRAPHICAL MAP OF FORTH & CLYDE AREA

The Edinburgh Geographical Institute

J.G. Bartholomew

Scale 10 Miles to an Inch

0 1 2 4 6 8 10 12 14

REFERENCE TO COLOURING

Sea level to 250 ft.	250 to 500 ft.	500 to 1000 ft.	1000 to 1500 ft.	1500 to 2000 ft.	above 2000 ft.

CHAPTER VI.

THE BURIED CHANNELS OF THE FORTH VALLEY.

THE next chapter in this fluviatile chronicle relates to events of a far later period, when the existing river-system was well established.[1] The land, as we shall be able to prove, still stood at a higher level in relation to the sea than it does in our time, but the rivers had deepened their valleys more than 500 feet since the events which have just been discussed. As there were no lakes to act as regulators and filters to the streams, the rain, when it fell, rushed down the glens in angry turbid torrents and hastened the work of valley erosion.

The evidence for the original valley-system described in last chapter is based on observation of the superficial and orographical features of the country, that any one can study with good maps, a little geological aptitude, and eyes for the physiognomy of the landscape. But now we have to deal with a different kind of evidence, far more difficult and costly to obtain, but once acquired, sure and unimpeachable.

In some parts of the Forth and Clyde area which have been referred to as made up of soft Carboniferous rocks, large quantities of coal and ironstone have been mined, and discovered by boring during the past century. While the pursuit of mineral wealth was the object of the boring, incidentally a great deal of important scientific

[1] This age is known to geologists as the Pliocene, the period that came after the Miocene and preceded the Pleistocene, which included the Glacial Epoch or Great Ice Age.

knowledge has at the same time accumulated, relating to the nature and depth of the superficial soil-covering of the land in these districts. Many hundreds, and even thousands of bores and shafts have been sunk to the rock, and by collecting and examining the records of these—a most laborious piece of work—geologists have been able to prove that both in the Forth and Clyde basins there is a system of buried river channels far below the present surface under or near the existing rivers and their tributaries. These are all filled up, and so deeply buried under beds of clay, sand, and detritus that, but for the operations of the mineral explorer, their presence and depth would never have been discovered or perhaps even suspected.

It is interesting here to note that in the Niagara district also a great deal of boring for oil and gas has been going on in recent years, and Dr. J. W. W. Spencer has, by examining and collating the records of the drillings, been able in the same way to discover and trace out the ancient channel of the buried river which, it appears, once ran by quite a different course from Lake Erie to Ontario.

No doubt the phenomenon is not an isolated one, and buried channels exist at many other places in this country under the principal rivers and estuaries, but where there is no valuable mineral to search for it is not likely that much boring will be undertaken for purely scientific purposes. A bore 300 feet deep through loose materials is a difficult operation, costing perhaps a pound a foot; and the expense has been so great that it is to be regretted a good many bores which had been begun have been given up, where the "surface" became very thick, at places where it would be of great scientific interest to find out the exact depth from the ground level to the solid rock.

The existence of buried river channels in Scotland seems to have been first discovered in 1869, when Dr. James Croll described in the *Transactions of the Edinburgh Geological Society* the results of an examination by Mr. James Bennie and himself of some two hundred and fifty bores made in the valleys of the Kelvin and Bonny rivers

on both sides of the water-parting at Kelvinhead. They traced the course of two gorges below the glacial drift filling the old gap, and running for most of the way along the lines of the existing streams. The eastern channel entered the sea at Grangemouth at a depth of 260 feet below mean sea-level, and the western in the Kelvin Valley was found to be 306 feet below the surface of the ground at Duntocher, near the Clyde at Old Kilpatrick. The buried channels of the Glasgow district have been lately investigated in much greater detail by the Geological Survey, and in the memoir published in 1911 a contoured map is given by Mr. Hinxman and Mr. Carruthers showing the pre-glacial topography of the valley very clearly.

Since Dr. Croll's time a great deal of mineral exploration of various kinds has been carried on, and in the Forth Valley I have collected many fresh data and done some boring on my own account, all of which has helped to throw fresh light on the old river-system as it existed both immediately before and after the Great Ice Age.

The Almond.—The Almond river, which now joins the sea at Cramond, had an older channel in pre-glacial times under Dalmeny House where the Dolphinton Burn now enters the sea. In the numerous borings for oil shale in that locality the course of the buried gorge has been accurately traced for about nine miles to the south-west. The Almond runs at places through glacial drift on the line of its original channel, but at a higher level, and at others it flows along a gorge more recently excavated in the rock. The old river was a steep one, no doubt, with numerous falls. Between Carlowrie and Midcalder the gradient was very high, about 31 feet per mile, and if this gradient was uniform the river must have entered what is now the estuary about 200 feet below the present sea-level. Carlowrie Haugh as seen from the Almond viaduct on the Edinburgh and Glasgow Railway is a comparatively tame little strath north of Ratho station, between low hills of whinstone, but at that time it was a picturesque glen more than 200 feet deep, and the

half-buried crags of Dolphinton and Dundas were then high and prominent objects of the landscape.[1]

The Avon.—The River Avon has for the most part cleared out its pre-glacial valley, but, as already mentioned, there can be little doubt its original course to the Forth lay in the direct line of its upper valley west of Linlithgow. The deep hollow, now the bed of Linlithgow Loch, between the volcanic range of Cockle Roy and Bonnytoun Hill is, no doubt, part of the ancient Avon Valley. This valley, as has been proved by borings, ran north-eastwards in a straight line and reached the main river on the east side of what is now the old basalt promontory of Blackness, but was then a conspicuous crag in the Forth Valley. During the Ice Age the Avon Valley became blocked up with drift, which is at places more than 100 feet deep, and the part east of Linlithgow was, when the great glacier retired, so obliterated, that the river found it easier to make a tack to the west and double round across the neck of soft rock west of Bonnytoun Hill, escaping by a shorter and steeper north-west passage to the Forth at Inveravon. The subsequent channel thus produced was in time deepened into a gorge which the river has occupied ever since. The Avon is a smaller stream than the Almond, and I have not yet found any trace of a very deep buried gorge along its course such as exists in the latter valley.

The Carron.—The Carron is a much more important stream than the Avon, and although, as explained above, it now only represents a fragment of the ancient river, it has, with its main tributary, the Bonny Water, been able in pre-glacial times to erode a deep and well-marked gorge, especially in the lower part of its course between Camelon and the sea at Grangemouth.

I have compared the borings and gone over most of the evidence collected by Mr. Bennie and Dr. Croll, which has been supplemented by more recent mineral explorations, but have not

[1] See the author's paper on the "Buried Channel of the Almond," *Trans. Geol. Soc. Edin.* 1903, p. 194.

found much to add to their results. Quite recently the Carron Company's workings in the Main and Upper and Lower Coxrod coals at Carronshore have encountered the buried gorge. In a bore near the present river at Carronbank, about 430 yards north-west of Dalderse Mill Farm, the depth to the rock was 285 feet, and the channel was filled chiefly with sand and loose materials. The surface of the ground is here about 22 feet above mean sea-level, so that the bed of the buried valley is 263 feet below ordnance datum at this spot. Neighbouring bores have proved the depth of surface deposits to be between 100 and 200 feet on either side, so that the deep channel forms a well-marked trench below the level of the deepest part of the neighbouring rock surface. The section given by Dr. Croll at Towncroft near Grangemouth is three-quarters of a mile further down the river, where the depth was found in two adjoining bores to be 42 and 45½ fathoms, or 252 and 273 feet respectively. In the adjoining Main coal workings of the Grangemouth Colliery, still further east, the coal was cut off to the south at a depth of 43 fathoms by a wall of clay running eastwards towards the mouth of the present river. From this point to Carron the course of the buried gorge has been accurately traced for three miles. It is, as I have already noted, a very difficult and costly business to bore a hole 40 to 50 fathoms down into running sand, clay, and loose materials, and some of the bores did not succeed in reaching the very bottom of the channel. This is unfortunate, geologically, but the channel must have been deeper downstream than at Carron, and the Towncroft bores probably did not strike the very lowest point.

In No. 6 pit workings at Carronshore the Main and the Upper Coxrod coals were cut off by the clay down to a depth of about 248 feet, but a level mine was successfully driven at a depth of 271 feet right under the trough, which proves conclusively that its deepest point at Carron goes down to 248 feet at least, but not so deep as 271 feet. As the coast at Grangemouth is three miles further down stream, and a river able to excavate such a gorge must

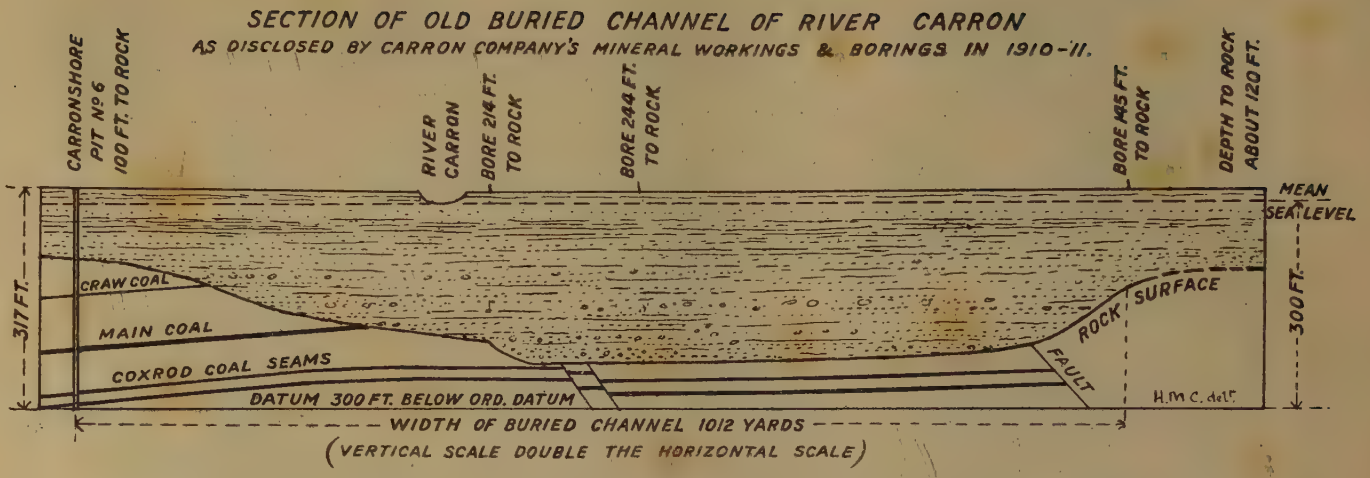
have been fairly swift and steep, it follows that the depth at the present coastline must be at least 280 and perhaps 290 feet below the surface. If, like the old Almond Valley, it had a fall of as much as 30 feet per mile, or even only 10 feet, the depth would then be considerably over 300 feet. This point is important in connection with what follows later.

The exact dimensions of the old glen are drawn on the accompanying section, the data for which were kindly supplied by Carron Company's engineer in March, 1912. At Carronshore it is about 1000 yards wide, but at other places the width is apparently not much more than 500 yards, and is less than this at some spots. The superficial deposits of the Carse near Grangemouth cover the whole rock surface to a depth of more than 100 feet, showing how great had been the erosion of the old Forth Valley before the great submergence at the Glacial Period. But in that old rocky land surface there had been scooped out glens 100 or even over 200 feet deep. No doubt there were also numerous side gullies and branches the courses of which we may never be able to trace.

River Devon.—The last of the old tributaries of the Forth of whose buried course I have been able to obtain a record, is the Devon between Tillicoultry and the Abbey Craig at Stirling.

The Devon is in some ways the most remarkable tributary of the Forth. It runs westwards for the last twelve miles of its course, against the direction of the main river, and seems, according to the code of common fluviatile law, to have no legal right to be in that position. The Devon, from the Crook westward, with its abnormal course, is a much younger tributary of the Forth than the others we have considered, and in this respect it shares the character of the Allan Water. Both are upstarts and robbers of other rivers' territory, and do not belong to any part of the old consequent river system of the Forth.

The Devon has two distinct sections. The higher reach of the iver issues from the deep trench across the centre of the Ochils, the


SECTION OF OLD BURIED CHANNEL OF RIVER CARRON
AS DISCLOSED BY CARRON COMPANY'S MINERAL WORKINGS & BORINGS IN 1910-11.
CARRONSHORE PIT No 6 100 FT. TO ROCK
RIVER CARRON
BORE 214 FT. TO ROCK
BORE 244 FT. TO ROCK
BORE 145 FT. TO ROCK
DEPTH TO ROCK ABOUT 120 FT.
MEAN SEA LEVEL
317 FT.
300 FT.
CRAW COAL
MAIN COAL
COXROD COAL SEAMS
DATUM 300 FT. BELOW ORD. DATUM
ROCK SURFACE
FAULT
H.M.C. del.
WIDTH OF BURIED CHANNEL 1012 YARDS
(VERTICAL SCALE DOUBLE THE HORIZONTAL SCALE)

This section shows the insignificant size of the bed of modern Carron water as compared with that of the ancient river.

southern end of which is called Glen Devon, and the northern Glen Eagles. Now Glen Eagles is the only deep pass across the range, and is occupied by a comparatively small stream running past Auchterarder into the Tay. But to go back to the original river-system this gap, whose present water-parting is about 750 feet in height, probably marks the course of a consequent river flowing first south-eastwards from the Glen Artney Forest, and then eastwards by Loch Leven to the lower part of the Forth Valley, or more likely north-eastwards from Loch Leven along the valley of the Eden between the Forth and Tay, at a time when all the land behind the Ochils was more than 750 feet above sea-level.

The volcanic ridge of the Ochils was a hard plank to saw, and the Forth Valley being now worn deeper at the Stirling gap than the higher-lying part of the Devon north of Glen Eagles, the tributary of the Allan Water succeeded in eating its way back and drawing off to the south-west some of the headwaters of the old Devon. The Tay was also at work, and its tributary stream the Ruthven Water also invaded the territory from Auchterarder on the north. Gradually Glen Eagles was thus dried up and became the bed of an obsequent stream running north into the Ruthven Water and the Tay. The other end of the old Devon Pass was attacked in the same manner by a tributary of the Forth eating its way back along the great fault-line skirting the southern face of the Ochils. In time the river was tapped by this industrious newcomer at the Crook of Devon and the water was diverted into the south-western channel, now the lower Devon Valley, so as to dry up the headwaters of the ancient Eden.

The Great Ice Age, it must be explained, was not a single continuous cold period, but was subdivided by one or more so-called *interglacial* periods with a more or less mild climate. This part of the Devon Valley may have been excavated during one of these intervals after the greatest cold had ceased. The reason for this supposition is the fact that the buried gorge is filled, not with the hard boulder clay produced under the great ice sheet of the coldest

Photo by Mr. A. Murray.

THE GORGE OF THE DEVON AT THE RUMBLING BRIDGE.

Excavated by the River in Old Red Sandstone Conglomerate.

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period, but with gravel and the red glacial clay deposited in sea water after the large glaciers had retired to the mountains, and at a time when the land was submerged and the sea stood at about 100 feet above its present level. These matters will be referred to at greater length in next chapter.

This appears to me the most feasible explanation of the peculiar course of the river, but its history by no means ends with this episode. We may now consider the later history of the Devon after the twelve-mile reach below the Crook had been permanently established. It is indeed difficult to see why, before the land was so much denuded down, the river should not have found its way directly south-eastwards past Saline to the Forth at Torry Bay. The reason probably is that the line of least resistance was along the great fault which skirts the Ochils and runs obliquely across the Forth at Stirling. The Forth had found a weak place to break through at Stirling, where the great faults that traverse the country had split the whinstone plateau with a line of cleavage of which the river was not slow to take advantage. A small tributary no doubt began to run off the slope east of the Abbey Craig into the Forth, and worked its way upwards and eastwards along the line of the Ochil fault. As the Forth was deepened and the soft Carboniferous strata were gradually worn away, the harder volcanic rocks of the Ochil range became more prominent, and the easiest track for the water to excavate lay along the junction of the hard and soft rocks. Once the little stream had started it kept its course, and as the main valley grew deeper, the tributary fed by streams from the high ground to the north was correspondingly deepened. After it had eaten its way back and tapped the old Devon, it would, like other predatory streams, be greatly enlarged and strengthened with the acquisition of so much more water.

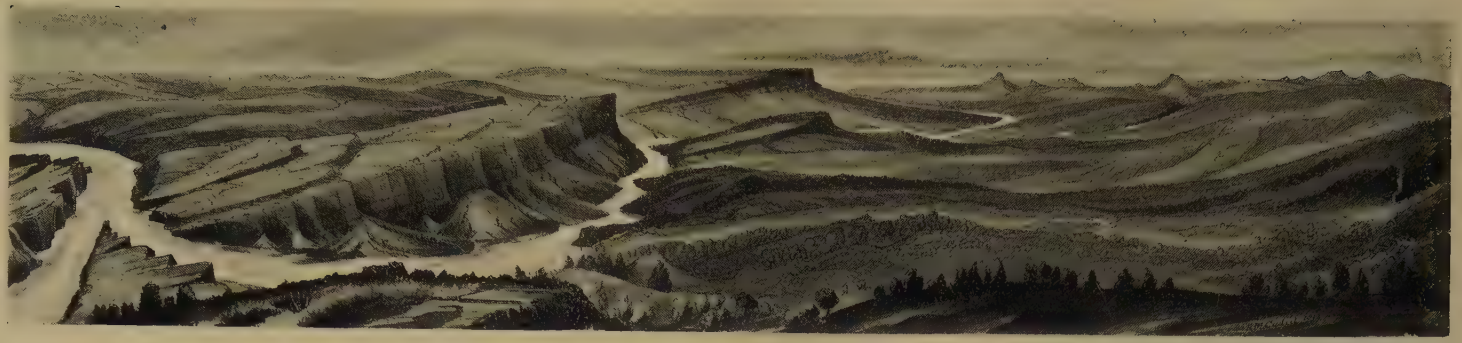
From Tillicoultry to the base of the Abbey Craig, a distance of six miles, the river runs in a straight course along an alluvial flat at the foot of the abrupt face of the Ochils, and further out the ground

rises slightly and the rocks of the Coal Measures appear on the surface in a low ridge extending continuously down to the Forth. A great deal of mining and boring has been done in this alluvial strip and along the river banks, and many bores have disclosed a deep and narrow gorge all the way from Tillicoultry to Blair Mains near Blairlogie. So far as I have been able to discover, no boring has been done to the east of Tillicoultry, but as the river is on alluvium all the way to Dollar, this buried gorge no doubt runs up past Dollar to the place where the river can still be seen at work extending the chasm, but at a higher level, in the well-known falls of the Cauldron Linn and the Rumbling Bridge.

The buried gorge which we shall now consider was, I believe, first proved by boring in the year 1826 on Alva estate, west of Tillicoultry. In that year one bore near the river found the depth to the rock to be 241 feet, and in several others more than 150 feet. In 1873 a neighbouring bore apparently nearer the centre of the channel went down 318 feet before reaching rock. In 1887 a third deep bore was made close to the river at Kersiepow, about half a mile further up, which proved the depth to be no less than 336 feet. A fourth bore made in 1872, close to the road at the public park on the west side of Tillicoultry, exactly a mile further up than the Kersiepow bore, struck the rock at 342 feet. This bore is on the 50-feet contour line at the foot of the hill slope, and shows that close to the Ochils the old gorge has been excavated to a depth of almost 300 feet below the present sea-level.[1]

This is the highest bore in the old valley that I have heard of, but at Glenochil Distillery, near Menstrie, a mile and a half below Alva, another bore was made for water which went down 330 feet before reaching the rock. The last of these interesting borings on the line of the old gorge was made so recently as October 1910. It was made at Blairmains, on Powis estate, two miles west of Glenochil,

[1] The cross-section of the buried gorge is drawn on a slightly exaggerated scale in the section showing the great Ochil fault in Chap. VII.



Confluence of the Forth and Devon before the deep channels were buried during the Glacial submergence.

The same place after the old glens were filled up, and the land had reached its present level.

PANORAMAS FROM THE ABBEY CRAIG AT STIRLING AT DIFFERENT PERIODS IN THE HISTORY OF THE FORTH.

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and proved the depth to the rock to be 305 feet. The ground is there about 40 feet above sea-level.

The old Devon thus occupied the deepest buried gorge that has been disclosed beneath the tributaries of the Forth, showing it to have been a swift river with great erosive power. The breadth of the channel at Alva was less than half a mile, and at Craigmill, at the east side of the Abbey Craig, seven miles below Tillicoultry, where it joined the Forth, it was not more than 600 yards across. The hard basaltic escarpment of the Abbey Craig projecting from the Ochil ridge deflected the last mile of the otherwise straight channel, causing it to bend southwards to the confluence with the Forth.

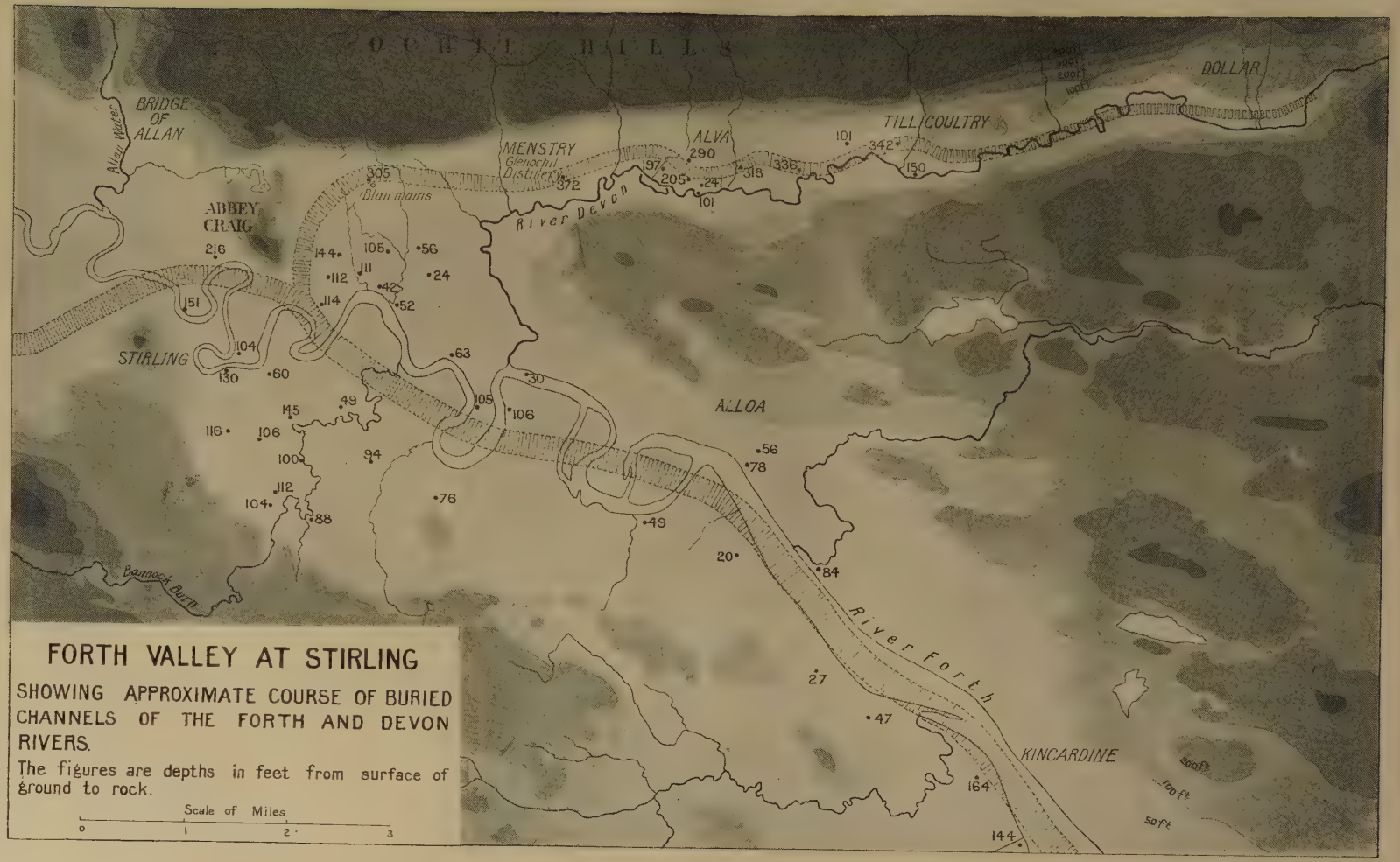
River Forth.—The course of the buried channel under the Carse is shown in the cross-hatched belt on the two shaded maps. The numerals on the maps are the depths in feet of different bores through the surface deposits to the solid rock. The first panoramic view is intended to show what may have been the appearance of the Forth Valley at Stirling as seen from the Abbey Craig at that time. The stream on the left is the Devon, and Stirling Castle Rock is shown as a great escarpment with a long slope of talus or "screes" at the base. The second landscape is a sketch from the same spot of the valley after being filled up and the land had reached its present level after the beginning of the human period. The aspect of the same landscape during the glacial submergence is shown at page 116.

There has recently been a great deal of boring for coal in the Carse of the Forth between Stirling and Alloa, and I am indebted to the various land and coal owners for kindly allowing me to use the information they obtained as to the nature and depth of the superficial deposits in that part of the Forth Valley.

At present we are not considering the kind of deposits found in these borings, but only the evidence they give of the depth and position of the buried river channel. It would have been a matter of great scientific interest if a single bore in the Carse of Stirling had

disclosed 300 feet or more of "surface," but out of a large number I have collected, not one bore seems to have reached the rock head at such a depth. Several of them, owing to the great difficulty in penetrating so great a thickness of loose material, after going down a considerable way, stopped and never reached the rock at all. So far as I have been able to ascertain, the deepest surface bore in this part of the Carse was at Causewayhead, near the river north of Stirling, where the alluvial deposits were found to be 216 feet deep. At the river south of Cambuskenneth Abbey, the rock was reached in two bores at 103 and 130 feet respectively, and a continuous series of bores extending to Drypow, two miles to the south-east, show the depth of surface to be between 60 and 145 feet.

From these it is clear that the old gorge must run further north than the line from Cambuskenneth to Drypow. From some borings north of this line it appears the rock is only 10 fathoms or less below the Carse between the mouth of the Devon at Cambus, and the mouth of the Powis Burn at Manor Castle. Indeed, in boring for a railway bridge opposite Cambus, the rock was found to be only 30 feet under the bed of the Forth. Two bores were however made south of this line, one at the Haugh of Blackgrange, and the other at Bandreath, in which the depth to the rock had dropped to 105 feet, and these seem to be near or on the north side of the gorge we are in search of. No borings have been made along a belt of ground three-quarters of a mile wide and two miles long, on the centre of which lies the old Polmaise House and policies at the east end, and the Haugh of West Grange at the west. If there is a deep gorge here it must occupy that position. As we follow it down the valley it must run through Tullibody Inch, Alloa Inch, and South Alloa; but it clears Alloa Harbour, as the rock is not deep on the north side of that part of the river. Borings to the south of South Alloa disclose only 75 feet of surface, and all the way down to Dunmore the rock is found at very shallow depths. On the north side of Clackmannan Pow, opposite Dunmore, it is only 84 feet



BURIED CHANNELS IN STIRLING DISTRICT INDICATED BY THE CROSSHATCHED BELT.

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down, and it is clear that the ancient gorge, if it exists at all, must exactly correspond with the present river-course between Alloa and Kincardine.

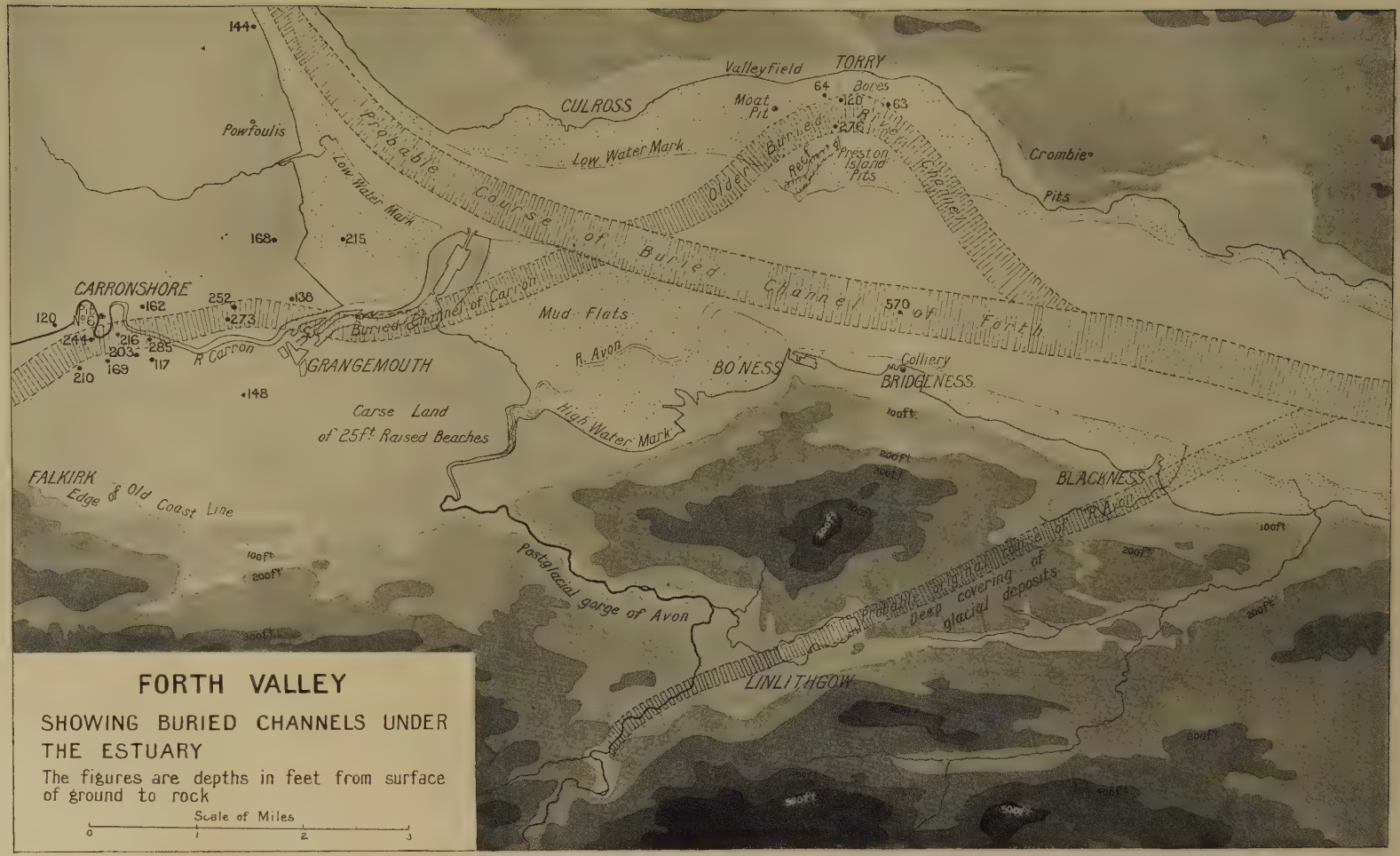
Coal workings have been carried on along both sides, but none have extended under the actual river bed, which at Dunmore is about quarter of a mile broad. Kincardine Ferry is four miles below Alloa, and the rock is quite shallow on the Kincardine side, but on the south bank at Higgin's Neuk, in a boring made by the North British Railway for a proposed tunnel about 1890, the depth of surface was found to be 164 feet. This no doubt indicates the south side of the gorge. The distance from high-water mark at Higgin's Neuk to the opposite bank at Kincardine is half a mile. Below Kincardine the river bed widens into the regular estuary. At Powfoulis, three-quarters of a mile below the ferry, a boring made by the Carron Company in 1904, 600 feet from the river, proved the depth to the rock to be 144 feet, and another bore, close to Powfoulis House and 2000 feet back from the bank, passed through 164 feet of surface before touching rock. The depth to the rock is less than this in the parts of the Carse further back from the river, so that there is no possibility of the deep gorge being situated anywhere except under the existing channel at this place.

At Grangemouth the Forth is joined by the Carron, and if we produce the line of the latter we find that it runs across the Firth towards Culross and Torry Bay. In a paper read before the Edinburgh Geological Society in 1881[1] I gave reasons for supposing that Torry Bay is on the site of another part of the buried river channel. The bay forms the arc of a circle, with a chord of three miles, stretching through Preston Island from Culross to Crombie Point. The coast recedes three-quarters of a mile back from this line, in the centre of the bay. In the centre of the bay, which is entirely dry at low tide, there is a reef of sandstone rocks, known as Craigmore,

[1] *Vide* "The Surface Geology of the Estuary of the Forth," *Transactions Edin. Geol. Soc*, Vol. IV. 1883, p. 6.

extending south-westwards for three-quarters of a mile from Preston Island to the edge of the foreshore at low-water mark. This is only an island at high tide, when the foreshore as well as the rest of the reef is covered. A belt of mud, three-quarters of a mile or more in width, sweeps round the bay between the island and the shore, the west end of which is generally submerged under a tongue of water known to seamen as The Strath. There is no doubt a geological reason for this. The shore of the bay is backed by low cliffs, and the sea does not eat away its coastline at this sheltered place. If it did, the sandstone island—the only island not of whinstone in the Firth—would have been the first part to be washed away. The only explanation appears to be that at one stage of the history of the valley, before the main valley had been eroded by the river, Preston Island belonged to West Lothian and not to the Kingdom of Fife. During the Glacial period the river course was changed by the great glacier, which like a good engineer straightened as well as deepened this part of the valley, and wiped out the old sinuosities of its track.

The evidence is not, however, entirely circumstantial. Coal-mining was carried on by Sir Robert Preston of Valleyfield, who a little more than a century ago sunk three pits on the island, and lost a great deal of money in them, partly, perhaps, because he did not know about the old river channel which separated the island from the rest of his domain. The deepest shaft was sunk to forty-six fathoms, and a water-level was driven 270 yards in a NNE. direction from the bottom of it towards Torry. At the end of this level the clay seems to have been reached at 276 feet below the surface, when the workings were abandoned in 1811. My father, who told me of the deep trough that Sir Robert had found, did some boring himself in the bay in 1839, and found the depth to the rock at the end of the old pier at Torry to be 63 feet. In another bore made more recently in the bay, but 870 yards further west, the depth was 120 feet, and in a third boring 200 yards still further west, and probably past the centre of the bend, the depth of surface was 64½ feet. The



BURIED CHANNELS UNDER THE ESTUARY OF THE FORTH AND THE ANCIENT COURSES OF RIVERS CARRON AND AVON.

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ancient Moat Pit of Sir George Bruce in the sea opposite Culross, to which King James VI. made his famous visit, belonged to quite a different colliery from that at Preston Island. The Culross Moat, which was connected by a subterranean passage with the shore, was sunk in the rock under the foreshore, some distance to the north of the old gorge. It was destroyed by a great storm in 1625, and the remains of the structure can still be seen in a heap of stones on the mud. There was, however, another old pit on the foreshore nearer Preston Island, called the Valleyfield Moat, the ruins of which are also faintly discernible. The position of the Valleyfield Moat enables us to trace out tolerably accurately the course of the buried channel lying between it and the Craigmore reef. The Moat, as shown on the map, lay 1100 yards NW. from the island, and the breadth of the deep channel between is probably not much more than 500 or 600 yards.

Why, it may be asked, was the old river originally deflected northwards towards Culross? The reason probably is that the hard ridge of the Bathgate and Bonnytoun hills, made up of volcanic rock interbedded with the coal-bearing strata,[1] originally extended further north than the promontory of Bo'ness, and thus formed an obstacle in the path of the river, which at all other places between Stirling and Queensferry had only soft strata to work upon. The whinstone beds, which, as explained in Chap. II., originally came from a volcano to the west of Linlithgow, thin out towards the north, and the river found an easier path round the end than across the back of the volcanic ridge. The influx of the Carron at Grangemouth may also have helped to push the stream towards the north of the confluence.

At Crombie Point, on the east side of Torry Bay, where coal was being worked in the eighteenth century, before the colliers received their liberty, tradition records a sad accident which has some bearing on the present investigation. The submarine workings suddenly tapped a bed of running sand that burst in and spread death and

[1] Described in Chap. II.

destruction through the mine. The late Mr. William Hurst, formerly locomotive superintendent to the North British Railway, who was a native of the district, writing in 1881, told me that sixty years previously an old collier in Fordell, named William Ramsay, had related to him how his grandfather, who was then a slave, had lost his life in the disaster. No doubt the miners suddenly struck the buried channel at an unexpected depth.

From Crombie Point eastwards it is not possible to trace the gorge with much accuracy. Lines of borings were carried across the estuary at three places in 1864 by the promoters of the first Forth Bridge scheme of Mr. (afterwards Sir) Thomas Bouch, the engineer of the first unfortunate Tay Bridge. It was found that there was everywhere an enormous depth of soft silt, even where the water was deepest. The late Mr. Thomas Wyllie, the contractor, who carried out the borings from the side of a steamer, told me that one day he pushed the boring rods right down into the mud without any trouble to a depth of 27 fathoms. Mr. D. Westland, C.E., has kindly lent me the Parliamentary plans, notes of boring operations, and evidence given by the promoters, from which it appears that in May, 1864, two bores went down 166 feet from low-tide level without getting to the bottom of the silt. In 1865 another set of borings was made between Blackness and Charlestown, and one of these, only about 500 yards from the coast at Charlestown, was sunk to a depth of 231 feet below low-water level without reaching the bottom of the mud. Boring through such materials was a marvellously quick operation. The deep bore just referred to, including the time required to put in the tubes, was begun in the dead of winter on 20th January, 1865, at 9.30 A.M. and by 10.30 P.M. the work was completed and the rods drawn up.

More recently a great deal of boring has been carried out at Rosyth, and a few bores have been made at Crombie Point about which Colonel Exham, R.E.,[1] has kindly given me information.

[1] The engineer in charge of the works up till the end of 1911.

These were not so deep as the old borings of 1865, but they tell the same tale. Outside low-water line the rock slopes steeply down under an immense deposit of soft silt, and it is only near the shore that the hard boulder-clay is to be found resting on the solid rock. The ancient river channel was outside the Du Craig, and the abyss between the south side of Bimar rock and the bridge, where the water alone is 41 fathoms deep, no doubt marks this part of its course. The south face of the Du Craig is a steep precipice plunging down to an unknown depth under mud, covering thick beds of red clay and other glacial deposits, but between the Du Craig and the north shore the rock surface is not very far down, and there is a good foundation for naval works.

When the Forth Bridge was begun I had many opportunities of visiting the works, including the deep foundations of the south cantilever which are built on the hard boulder clay that extends most of the way from Inchgarvie to the south shore. The depth halfway between Inchgarvie and the south shore, where the water is 37 feet deep, was found in the borings for Mr. Bouch's proposed bridge in 1870 to be 102 feet from high-water level to the top of the boulder clay which overlies the rock. No doubt the deep gorge of the old river was on the north side of Inchgarvie where, but for the water that fills it, the chasm is still open to a depth of nearly 40 fathoms.

That some parts of the old bed of the Forth are far deeper than 300 feet there is, however, direct evidence. In the submarine coal workings at Bridgeness and Bo'ness, on the writer's estate of Grange, directly opposite Crombie and Preston Island, the seams have been worked northwards to the outcrop where they have been abruptly cut off by a steep barrier of boulder clay, full of ice-worn stones and boulders of various kinds of travelled rock foreign to the district. The edge of this barrier has been followed westwards in the workings for more than a mile, and the greatest depth at which it has been encountered opposite Bridgeness is no less than 570 feet below high-tide level at a distance of nearly half a mile from low-water

line. But so far there is no evidence that this is the deepest part of the buried valley, as the rock abuts against a more or less steep face of clay the bottom of which has apparently not yet been reached.[1]

It is, however, doubtful to me whether this is to be regarded as the original pre-glacial river bed, or a later rock basin deepened by glaciers like the western lochs, which are sometimes more than 600 feet in depth. If the original Forth ran round Torry Bay, as I have suggested, it could hardly have occupied another and deeper channel at Bo'ness at the same period. I am rather inclined to think that Torry Bay marks the site of an original loop in a more or less serpentine channel, which, according to the common habit of rivers, was subsequently cut off by the river straightening its course. The large glacier of the Ice Age under which the hard boulder clay was manufactured moved in a straight and even course, and no doubt scooped out the underlying soft rocks to a considerable depth and produced a true rock basin below sea-level, like the West Coast lochs, which extended for several miles like a straight gutter along the centre of the valley. In the workings of the Grangemouth Colliery five miles further west the boulder clay under the foreshore has also been approached from below, but at a depth of only 215 feet, but this is at a greater distance from the centre of the channel than the Bridgeness workings.

Further mining developments are necessary to solve the problem completely and decide whether or not this is a true ice cut rock basin. As we have seen, the buried gorge of the Devon, excavated apparently by river action and not by ice, is entirely filled with fine red silt, mud and gravel, apparently all deposited by water, and not with hard boulder clay firmly compacted by the pressure of huge glaciers. The other buried river channels all contain more or less sand and gravel of fluviatile origin as well as local beds of true boulder clay, produced

[1] *Vide* sketch section of glacial deposits at Bo'ness, where the coal seams are shown cropping out against the south edge of the buried valley, page 107.

between interglacial periods after the time of maximum glaciation had passed away.

But what we have been considering is mainly the action of running water and the origin of the old river system, and not the effect of the Ice Age on the Forth district. That episode is too important to be adequately dealt with at the end of this chapter, and all that I have done is to make a few passing references to it in connection with the other points relevant to the discussion.

This discussion and investigation of the buried channels is of interest for two reasons, one of them scientific and the other economic. From the first standpoint it is clear that since the river occupied the deep channel a great submergence has taken place. We saw that in the Devon Valley the old river bed reached down to 300 feet below sea-level, and the Carron was probably also as deep at the mouth. But the changes in level were regional and not confined to one part of the country. In the Clyde basin Mr. Bennie found the buried channel of the Kelvin at Duntocher to be also about 300 feet deep, which shows that the amount of submergence of Scotland was at least 300 feet. No doubt there is also a buried channel under the bed of the Tay to which reference will again be made.

But the Devon, the Carron, and the Kelvin were only tributaries of much larger rivers which carried all the sediment away to a great distance and kept the side valleys quite clear. Between Stirling and Kincardine we saw that the main river must have had only a narrow gorge, the maximum depth of which has not yet been fathomed by the borer's tool. But if the channel had a small width it must have had steep sides and a great depth to vent a large volume of water. The buried gorge of the Kelvin was found to have perpendicular and even overhanging walls at some spots. It must likewise have had a steep declivity and a swift current. Now let us take the gradient of a river such as this at say seven feet per mile, which is much less than that of some of its tributaries, but is nearly the average declivity of the Colorado River for 218 miles through the Grand Cañon district.

Let us now multiply this by the distance between Stirling and Queensferry—23 miles as the crow flies—and we find we must add about 160 feet to the depth of the gorge, which below the bridge must thus be at least 460 feet below the level of Inchgarvie. In other words, if the land were again upheaved to its ancient position, and the water and mud were swept away, the north cantilever instead of stretching across the sea at a height of 120 feet, would be found to span a chasm 160 feet deeper than that of the Zambesi, with a swiftly rolling torrent no less than 580 feet below the level of the rails.

The accompanying sketch is an imaginary view of the valley at that period as seen by a spectator looking eastward from the vicinity of Blackness. The shadow of the bridge (drawn to scale) has been introduced to show the relative dimensions of the glen and its surroundings. Inchgarvie and Bimar rock must have been pinnacles of imposing dimensions in that ancient landscape.

But the old river, no doubt, ran far beyond the Bridge, and therefore the whole elevation of the land above its present level was probably far more than 400 or 500 feet. The North Sea between Scotland and Denmark is, except at a few places, less than 50 fathoms deep, and therefore, if the land were lifted even 300 feet, *that vast expanse of ocean would nearly all be dried up*, and the British Islands would become merely a mountainous portion of the European continent projecting far out into the North Atlantic.

At the time we are speaking of, the buried river valley shows that this was the condition of our country; the North Sea had no existence, and we had no silver streak drawn around our shores by a kind Providence, but only a vast plain on our unprotected eastern border, across which the Forth, Tay and other rivers meandered away outwards and perhaps became tributary to some greater river flowing into the Arctic Ocean. If the climate was no colder than it is now, the addition of only 500 feet to the height of the mountains would also raise the higher summits above the snow-line, and the melting

THE ANCIENT FORTH VALLEY AT QUEENSFERRY WITH THE SHADOW OF THE FUTURE FORTH BRIDGE CAST ACROSS IT.

To face page 100.

snows in spring would greatly add to the floods in the Highland rivers.

The second or economic aspect of the subject relates to the effect of these concealed channels on mining and tunnelling operations. Serious accidents have happened at other places besides Crombie Point, where old river courses have suddenly been met with. Dr. Croll says the late Mr. Dawson of Carron told him that about 40 years before 1869 the miners in the Carronshire pit cut into the trough of the Carron at a depth of 40 fathoms, and the running sand rushed in with irresistible pressure and filled the working.[1] Mr. Bennie described a similar disaster where the old Kelvin gorge was struck in a colliery near Duntocher at a depth of fifty-one fathoms, and the sand burst in and killed several miners.

Various proposals have been made to connect the north and south shores by driving tunnels under the Forth, but in view of the hidden river bed, it is perhaps well that none of these have been attempted. In 1880, after the fall of the Tay Bridge, a scheme was set afoot to run a tunnel from Hound Point to Donibristle instead of risking a dangerous bridge. From a copy of the plan in my possession it appears that there was to be a line of railway running from Granton along the shore to Cramond where the tunnel was to begin. At Cramond the line was to be continued underground in a tunnel running downwards at a gradient of 1 in 75 until at Hound Point near Dalmeny it had reached a depth of 200 feet. At this depth it was to bend northwards under the sea and run to Donibristle on the north shore, where it was again to bend eastwards and emerge to the west of Aberdour. It will be quite clear from what has been said that this scheme was proposed in entire ignorance of two buried channels crossing the line of the railway, both considerably deeper than the tunnel level. First the old channel of the Almond at Dalmeny House, more than 200 feet in depth, would have to be pierced by the tunnel, which was proposed to be only 100 feet deep at that place, and secondly

[1] *Trans. Edin. Geol. Soc.* Vol. I. p. 336.

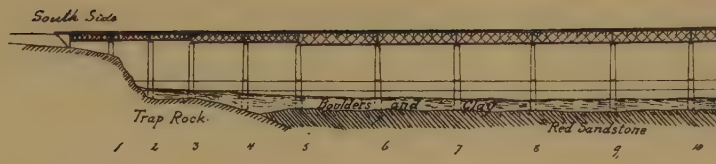
the far larger buried channel of the Forth probably filled with mud and sand to a depth of over 400, and perhaps 600, feet. Fortunately for the promoters the scheme never even reached the experimental stage.

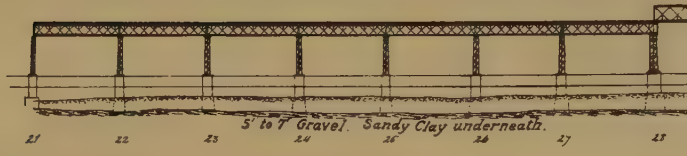
Another proposal to tunnel the Forth at Kincardine Ferry, already referred to, was made by the North British Railway Company in 1890-91, when parliamentary plans were prepared, and some preliminary boring was begun. The tunnel was to be only about 59 feet below low-water level, and as the buried channel is more than 300 feet deep here, and it is probably full of soft mud and sand, the making of a safe tunnel through it would have been a very costly and dangerous piece of work if, indeed, it was feasible at all.

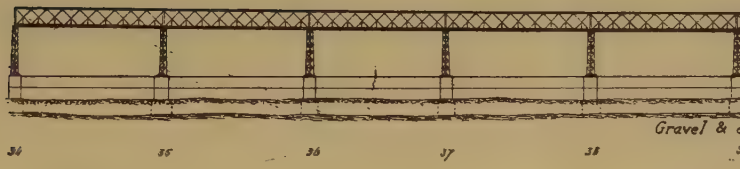
Another practical point may be noted in conclusion. When the original ill-fated Tay Bridge was designed in 1870 it was expected that the solid rocky bottom that had been found near the shore on both sides would extend all the way across the estuary and afford a good foundation for the heavy brick piers on which the superstructure was to rest. But alas for these unscientific expectations! After the bases of fourteen piers had been safely laid from the north side to a distance of 516 yards along the line, the rock suddenly began to slope down to an unknown depth, as is shown in the accompanying illustration, reduced from a larger drawing by Mr. Grothe the resident engineer on the works. When No. 15 pier was sunk it only touched the rock on the south side, but the north side having a soft bottom caused the structure to cant over so dangerously that it could not be righted and had to be demolished. This led to the alteration of the whole original plan, as the greater part of the bottom was found to be soft from No. 14 pier to the north shore, and unable to bear the heavy superstructure originally designed for the piers.[1] It is now a matter of history how, on the dark stormy night of 28th December, 1879, this frail cast-iron superstructure proved unequal to the strain, and the

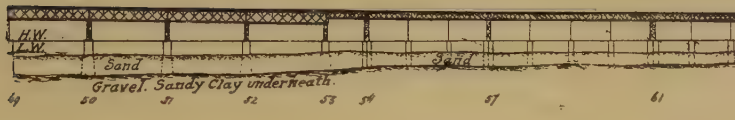
[1] *Vide* Mr. Albert Grothe's description of the (*First*) *Tay Bridge; its History and Construction* (Dundee, John Leng & Co., 1878), written just after the opening of the railway.

ELEVATION





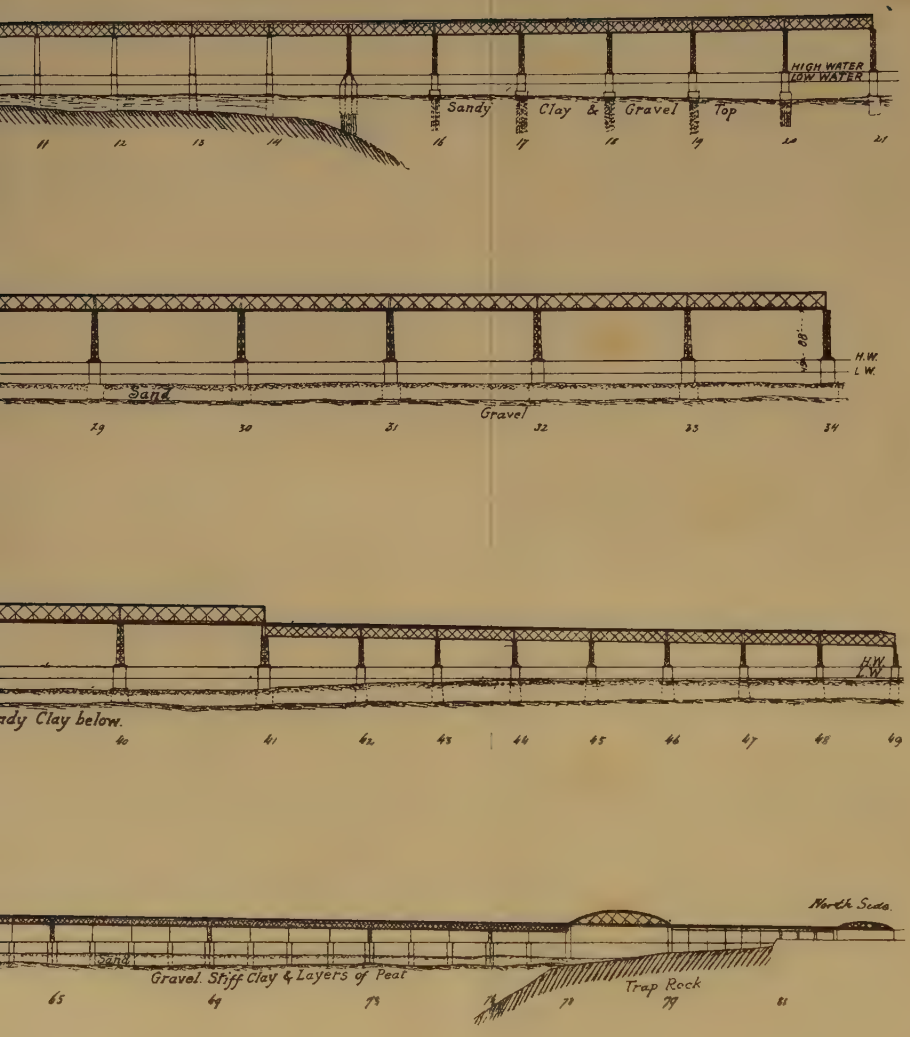




A REDUCTION OF MR. A. GROTHE'S

The first 14 Piers are shown resting on solid rock. The 15th Pier was fo
the north

OF THE TAY BRIDGE.



ale 320 feet to 1 inch.

RAWING OF THE ORIGINAL TAY BRIDGE IN 1878.

ed on the edge of the Buried River Channel, which occupies nearly all the rest of the section to
, and is filled with soft material.

thirteen large spans in the centre gave way about a year and a half after the bridge was opened, precipitating a passing train into the deepest part of the river with ninety passengers, not one of whom escaped to tell the tale. The Board of Trade inquiry proved that the fault lay principally in the cast-iron columns bearing the girders, which had been badly made and too cheaply erected, and as they were an afterthought consequent on the belated discovery of the buried channel, it becomes evident now that the engineers' want of geological knowledge of the old river-system was an important contributory cause to that terrible calamity. Engineers cannot afford to discard scientific evidence, and this investigation may perhaps be of use in connection with other schemes for bridges over or tunnels under British estuaries, as buried channels will no doubt be found to exist at many other places besides those I have spoken of.

CHAPTER VII.

THE GREAT ICE AGE.

THE climate of the previous ages must have been mild and genial and even warm at times, since vegetation and animal life can only exist where the ground is free of frost and snow for the greater part of the year, and when the sun shines brightly on a land well moistened with a sufficient rainfall.

But at the end of the Tertiary period, in what is known as the Pleistocene age, a change of climate set in, the proofs of which can be seen on every side. For many years geologists busied themselves studying the so-called "drift" deposits that are sprinkled or thickly spread over the rock surface in every part of Scotland. It is needless now to recapitulate the lively controversy which arose as to the origin of these deposits, as the whole matter has been very ably dealt with in Professor James Geikie's *Great Ice Age*, and as the main points in the problem have now been definitely settled among geologists both in Europe and America.

The Boulder Clay or Till.—Covering the rock there is generally to be found in Scotland and in the North of England a very dense unstratified bed of coarse clay, often sandy and full of pebbles, blocks and boulders of all shapes and sizes. It is quite different in character from anything in the solid rocks beneath, and also from the overlying stratified clays and gravels which have been transported by rivers and deposited in water.

This curious stratum is known in Scotland as the *Boulder*

Clay or *Till*, and is found on investigation not only to be made from local materials mixed with the debris of a great variety of rocks that have come from distant places, but also to be intensely hard and dense. In fact, it is so hard and tough that in making excavations for dock walls, etc., it has often to be blasted out like solid rock. The stones in it are, moreover, nearly all seen to bear traces of grinding and scratching, and are sometimes well worn and rounded on one side, while quite rough and angular on the others. Three things are thus mainly characteristic of the till:

(1) It is made of transported as well as of locally derived materials.

(2) It has been produced under enormous pressure.

(3) It has been ground, squeezed, or pushed along so as to mix up, scratch and striate the stones which it contains. Further than this, the rock surface is always found to be scratched and striated wherever it lies directly under the till. The deposit is, as a rule, perfectly unfossiliferous, but if in rare cases it should be found to contain a few vestiges of plants or animals, these are in a broken and ground-up condition, worn and striated like the stones that surround them.

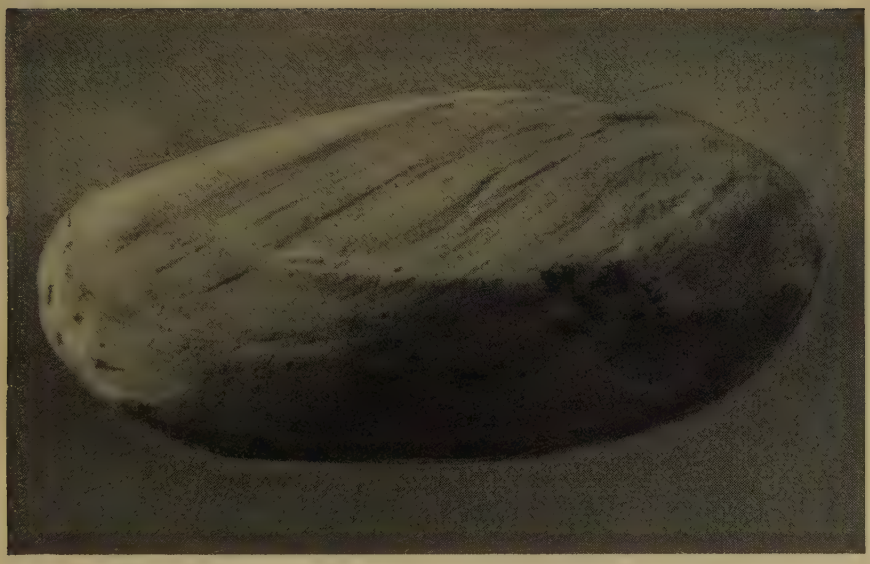
The Great Ice-sheet.—It is clear, therefore, that these and other characteristics can only be explained by one hypothesis. The till must have been produced beneath an enormous glacier, an abnormal visitor, that once crept over Scotland and enveloped the whole country, just as glaciers cover Greenland at the present day. The density of the deposit was caused by the superincumbent pressure of hundreds or thousands of feet of ice. The variety of the stones is due to the transporting power of the ice in its long journey across various formations from the Highlands to the sea.

The striation and polishing of their surfaces and that of the underlying rock is the result of the slow movement of the flowing ice, which sometimes dragged along the stones, and at other times slid over the accumulated offscourings of the land, and pressed them together into a solid amorphous mass.

The Ice Age was, however, not all equally or continuously cold from beginning to end, and it was only at the time when the climate was most severe that the ice-sheet swelled to such vast dimensions. We shall now notice, in the first place, some of the effects of this terrible invasion by the irresistible legions of John Frost, when the cold was at its height.

The land had apparently enjoyed a mild climate for a long period, and there was, no doubt, an accumulation of good soil on the alluvial flats and gentle slopes of the valleys. When the hills became covered with perpetual snow, and when the increasing snow produced valley glaciers which gradually swelled and advanced on to the low ground, all this soil was ploughed out and pushed forward with irresistible pressure from behind. As the cold increased in intensity, the icy flood swelled higher, and the glaciers overflowed the confines of their original valleys, and at last all coalesced into one universal flood of ice which crept outwards on all sides and disregarded the smaller impediments in its path. The higher summits rose through it like islands, but the lower hills were completely smothered, and the ice-sheet even swept over the tops of the Ochil and Pentland ranges, and left its marks on their very summits. The Ochils reach a height of 2300 feet in the summit of Ben Cleuch, and the whole range, like other ice-worn places, is well rounded on the crests, as if rubbed smooth by an immense sheet of sandpaper.

Depth of the Ice-sheet.—I have already referred in a former chapter to the outcrop of the coal seams in the submarine workings at Bridgeness and Grangepans, where the underside of the buried channel of the Forth, marking the bottom level of the glacier, has been repeatedly struck at various depths. The first time this occurred, about forty years ago, what is known as the ironstone and parrot coal seam was actually worked for about fifty yards with a roof, not of Carboniferous rock, but of *Boulder Clay* so strong and hard that the miners thought it was solid rock. This was at a depth of only 137 feet below sea-level. The first warning that it was not really a



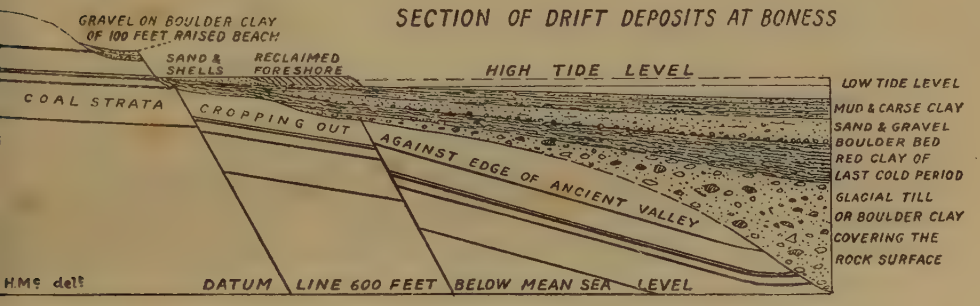
ICE-WORN BOULDER OF SANDSTONE.

Weighing 7 cwts., found at the Outcrop of a Coal Seam below the Buried Valley of the Forth at Grangepans, 137 feet under the sea level.

To face page 106.

solid stratum to be trusted overhead, was the dropping out of the roof of a large ellipsoidal-shaped boulder of hard gray compact sandstone, 7 cwts. in weight, which nearly fell on the top of a man. When brought to the light of day it was found to be beautifully striated with flutings reminding one of a clam shell. This interesting stone has been preserved, and the characteristic glacial striae are shown on the figure, which is taken from a recent photograph.

The bottom of the channel has been struck in the workings at many other places since then, and other travelled boulders have been


SECTION OF DRIFT DEPOSITS AT BONESS
GRAVEL ON BOULDER CLAY
OF 100 FEET RAISED BEACH
SAND & SHELLS
RECLAIMED FORESHORE
HIGH TIDE LEVEL
LOW TIDE LEVEL
COAL STRATA
CROPPING OUT
AGAINST EDGE OF ANCIENT VALLEY
MUD & CARSE CLAY
SAND & GRAVEL
BOULDER BED
RED CLAY OF LAST COLD PERIOD
GLACIAL TILL OR BOULDER CLAY COVERING THE ROCK SURFACE
H.M.S. del.
DATUM LINE 600 FEET BELOW MEAN SEA LEVEL

brought up to the light of day. The deepest place where it has been met with, as mentioned in a former chapter, is 570 feet below high water level, half a mile north of low-water line at Bridgeness. This may either be an old river channel or a true rock basin hollowed out by the glacier, like the deep West Coast lochs, or the profound Norwegian fiords, which sometimes reach depths of 2000 or even 4000 feet below sea-level. The general section of the drift deposits and the depth of the river valley at the outcrop of the coal is shown in the accompanying figure. If we now add these two figures—the height and the depth—together, we find that the ice-sheet which swept over the Ochils and filled up the buried valley must have been at least 2870 feet thick. It was probably much more, as that sum allows nothing for the thickness of the ice above the highest point of

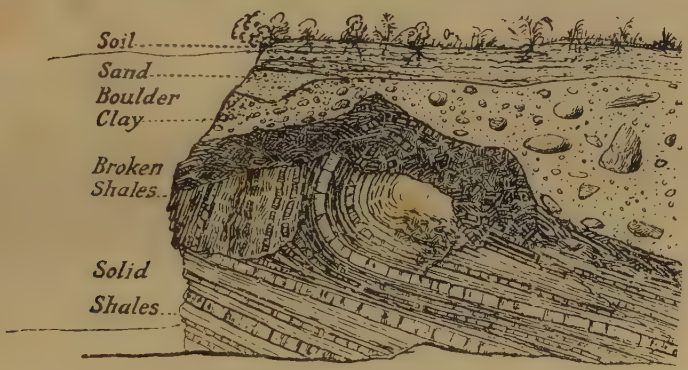
the range, and 570 feet may not be the deepest part of the trough. No doubt the glacier was more than 3000 feet deep at one time—probably far more—and the pressure on the loose materials and the underlying rock must therefore have been enormous—more than half a ton on every square inch.

The stream of ice behaved like a river in one respect. It moved bodily forward, and the lower parts did not stagnate and lie dead in the hollows and allow the upper layers to slide over them. The upper surface naturally moved fastest as it sloped gently all the way from the snow-field at the source to the edge of the glacier, where it broke into bergs in the distant ocean. But the bottom section of the stream moved also, plunging down into hollows and creeping out of them and pushing its way slowly upwards on the other side so as to override all obstacles in its path.

Rock Basins.—The consequence was that every loose object was scoured off the face of the land, and the softer parts of the rock were scooped into troughs and basins. Some kinds of crystalline rock, particularly those containing much felspar, are apt to decompose to considerable depths, and anyone who wishes to study this rotting of the surface will find it well exemplified in the crumbling basalt cliffs at North Queensferry. In the Australian goldfields and elsewhere the so-called oxidised zone of the country rock extends down to more than 100 feet at some places, while at others close by the rock is perfectly fresh and undecomposed. There was thus probably, at first, a great deal of rotted rock for the glaciers to work upon, as the land had been long exposed to a mild and moist climate with plenty of running water trickling over the surface, and percolating far down into the pores and fissures below. These soft spots would be very unequally distributed, and would be mostly located along lines of weakness and cracks into which the water could most easily penetrate. Where the rivers had previously excavated glens the ice would, of course, produce the greatest effect, especially at places where the valleys were narrow and the flow constricted.

We thus find in all countries which have been lately glaciated multitudes of true rock basins produced by former extensions of the glaciers, and could the ice covering be lifted off Greenland we should find it covered with lakes freshly hollowed out of the solid rock.

The tearing and ploughing up of the softer kinds of rock under the glacier is sometimes very apparent where there is an outcrop of flaggy strata or beds of shale. The following illustration of this sub-glacial contortion is taken from a sketch of a fine section of the Wardie shales above the Craigleith sandstone, that was exposed when the east side of the deep quarry was being worked in 1880.



The section was about 10 feet deep, and the shales under the till were torn up and smashed for a distance of 28 yards. The ice pressure came from the west or left side of the section, curling up the shales towards the right.

But this was only one effect of the ice-sheet. It can easily be understood that the enormous volume of debris scraped from the pre-glacial land surface would soon accumulate to such a depth that the glaciers could no longer plough through it or push it along. The boulder clay is sometimes 50 to 100 feet thick, and it lies in greater or less quantity over nearly all Scotland, and at these places where it is thickest the ice, no doubt, slid over its surface and squeezed it very tightly together. At such places where there is a great depth

of till the land is cold and poor owing to the want of porosity of the soil, the difficulty of draining it adequately and the enormous number of worthless stones scattered through it. Large tracts of low country have thus been almost ruined agriculturally by the ice-sheet, and some have been swept entirely bare of soil like the west coast of Sutherland and Ross. The reclamation of such tilly land consists principally in laboriously picking the stones out of it and draining and ploughing the upper surface to allow the air to penetrate. In the Lothians the farmers are still occupied every spring in gathering heaps of these stones from the cultivated ground and removing boulders which are turned up from the subsoil even after a century of good agriculture. If this is still necessary, what must the land have been like in the times of our poor ancestors before they had begun to reclaim the stony wilderness and turn it into the fertile fields which we now associate with the name of this part of Scotland?[1]

The Track of the Great Glacier.—It is possible to trace the course of the great ice-sheet by observing the direction of the ruts or scratches deeply engraved on the harder rocks, and also from the boulders it has left scattered along its path. If we take the case of a hill, say of granite, isolated amid other kinds of rock, and if from this well-defined source we find issuing a stream of granite boulders sprinkled along one general line like scent in a paperchase or grains of corn on a country road marking the track of a shaky miller's cart, then we can tell with certainty which way the ice travelled, and we find that these two witnesses—the stones and the scratches—agree in the kind of evidence they give. By this means it has become possible for geologists to make a map showing the extent and path

[1] F. St. Fond in his journey in 1784 from Edinburgh to Carron, referred to in Chap. X., says that the whole district at that time was covered with blocks of volcanic rock. He was much interested in volcanic phenomena, and was thus apt to exaggerate their effect. What he noticed was not the products of widespread volcanic eruptions, but the boulders left by the old glaciers that had not been cleared from the land. Many of these were not of volcanic origin at all.

of the great ice-sheet which lay for thousands of years like a vast octopus over not only Scotland but the whole of Northern Europe, and sent its far-reaching limbs crawling outwards on every side for hundreds of miles down the valleys and over the plains that lay within its cold embrace.

The ice in the Forth Valley moved almost due eastwards, and among the many kinds of stones in the till we find quantities that can be traced to the Ochils, and the Highlands to the west, but we hardly ever come across a granite boulder in the collection, because granite is almost non-existent in the high ground to the west where the ice came from. I once took the trouble to count the different kinds of stone in an area of till exposed on the shore near Blackness, and out of 336 stones only two, or a little over a half per cent., were granitic in origin. The whinstone on the top of Bonnytoun Hill overlooking Bo'ness, 550 feet above the sea, is well striated from west to east, and all over the district, wherever the rock is hard enough to retain the ice-marks, the grooves are found to point in nearly the same direction.

The great glacier moved eastwards over the bed of what is now the North Sea, and there it met a far larger stream of ice flowing outwards from the snowfields of Scandinavia. The Scottish ice was thus turned from its straight course and deflected northwards towards the Arctic Ocean. The whole united stream must have been of prodigious size, for it covered the Orkney and Shetland Islands and grooved the rocks from shore to shore in a north-westerly direction, leaving some Scandinavian boulders scattered about to tell the tale.

At that time the land was, no doubt, several hundreds of feet above its present level, and the old river valleys confirm what we should otherwise suppose to be the case from the glacial evidence alone. Unless the land had been very high how could there be a sufficient gradient to permit the glaciers to flow for hundreds of miles outwards from the Firth of Forth over the Orkneys and Shetlands and round towards the Färoe Islands? Ice, like any other

fluid, however viscous, needs a certain amount of fall, and cannot possibly travel for 500 miles along a perfectly level course. If the land was thus higher it was also nearer the snowline, and the temporary elevation may have had much to do with the increase of the cold at the time of maximum glaciation.

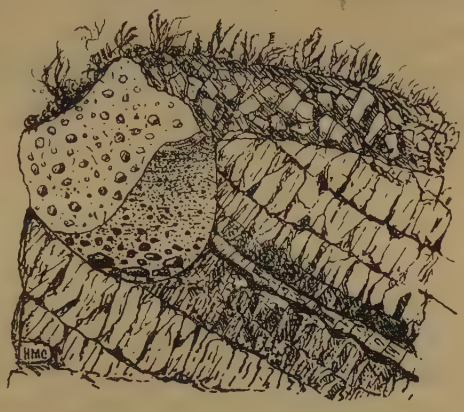
The Submergence.—But this was not the whole cause of the Ice Age. A time came when it was still cold, although the greatest cold had passed away, when the land sank several hundreds of feet, and the subsidence did not stop till the sea had risen to a height of about 100 feet above its present level. This part of the old continent was thus, perhaps for the first time, cut off from the rest of Europe, and the North Sea rose over the plain and turned our outlying corner into a detached group of islands. The lowering of the land was not, however, accompanied all at once by a change of climate. At the time of what is known as *the* 100-*feet raised beach* the climate was still cold. The Firth of Forth was then full of floating ice and bergs, that carried rubbish and stones from the glaciers, still lingering among the glens and Highland hills beyond Dunblane.

Interglacial Periods.—The deep submergence took place at the end of the Ice Age, but before that event happened it is only proper to mention here that there were several interludes called *interglacial periods* in which the ice melted away and the climate became mild and genial for a time. This is proved by the presence of gravel and sand in large beds in sheltered hollows between beds of true boulder clay. Gravel is produced not by ice but by running water, and the ice must therefore have disappeared and given place to rivers at these periods. When the cold returned the alluvial deposits were not ploughed out in all cases but were sometimes securely covered up by till over which the glaciers crept smoothly along.

In 1881 the writer described a small stream channel which was then to be seen in an old whinstone quarry above Bo'ness.[1] The

[1] *Trans. Edin. Geol. Society*, Vol. IV. 1881, p. 12.

following figure is a sketch that was made of the section. The lower part of the channel was partly filled with gravel, which was covered by a bed of true till. Now it may be asked, why cannot this have been made by a small preglacial burn instead of by an interglacial streamlet? The answer is that on examining the pebbles the gravel was found to be chiefly made up of fragments of foreign rocks which must have been brought from a distance by an older glacier than the one which produced the covering of till. The gravel represents the washing of an older bed of boulder clay which covered the country with travelled stones before the stream began to flow, and we have thus a proof, in a small local corner, of a phenomenon which has been noticed by glacialists in a great many far more important places.



Glacial Deposits.—In the bed of this part of the Forth Valley four or five more or less distinct superficial deposits are generally to be found above the rock. These have been disclosed in greater or less thickness by many borings and sinkings all over the estuary. They are depicted on the section at page 107, and are as follows:

Carse clay, with shells.
Sandy mud or silt, with stones.
Red clay.
Sand (not always present).
Boulder clay or till.
Rock.

The boulder clay of the Forth Valley is generally dark blue or almost black, except at places where it is above sea-level and has

been oxidised on the surface to a brown colour. In sinking a pit at Bridgeness at low-water mark, however, there was found an irregular bed of about 12 inches of distinct red till entirely made up of fragments of Old Red Sandstone rocks above the black boulder clay bed next the Carboniferous strata. This shows that the glacier had dragged along a quantity of debris from the Callander district, 25 to 30 miles away, which was not mixed on its way with any local material. It is possible there may have been an interglacial period between these two divisions. There must, at all events, have been some interruption to the continuity of the glaciation. The red till was covered by a few feet of fine sand which shows that the ice had disappeared and given place to running water. Above the sand was the red clay that forms a distinct and widespread deposit in the low ground of the Forth Valley, 30 feet or more in thickness.

The Red Clay.—This has been pierced in hundreds of shafts and bores, and is developed to an enormous thickness in the Rosyth district at St. Margaret's Hope. It is a fine, plastic, chocolate-pinkish- or brownish- coloured clay, often showing delicate laminations or streaks of lighter or darker tint, some of which contain very fine sandy partings, as if the deposit had been affected by the flow and ebb of the tide. It rarely contains shells or traces of organic remains in the upper part of the estuary. In the Rosyth dock excavations and at a few other places it contains some ice-worn boulders of travelled rock. The inference is that this is a glacial deposit, formed, however, not under a glacier but in a frozen sea where there were distant glaciers producing quantities of thick impalpable mud which was carried down the estuary and deposited in deep, cold and comparatively tranquil water, perhaps under the ice. At times, however, the ice broke up and floated away in bergs or large cakes, carrying boulders and striated stones which had been originally brought down by the valley glaciers. These ice rafts dropped their burden quietly into the soft red mud as they melted away. In the excavation for the Bo'ness Dock in 1881 hardly any stones were found in the clay

itself, but on the top of it there was a well-marked bed of boulders, some of them of large size. The ice had evidently melted at last and a general thaw had set in and released whole fleets of ice rafts from the pack or ice foot which had fringed the coast and held the boulders fast in its frosty grip.

The 100-feet Raised Beach.—This red clay is only found in quantity in the bed of the estuary below sea-level, and to a limited extent along the shores. It never occurs above the 100-feet contour line (and indeed very seldom reaches so high), but it appears to have been deposited when the sea stood 100 feet or so above its present mean level. At that elevation there is at many places a well-marked notch or terrace in the coastline, cut into the boulder clay or rock and covered with a few feet of gravel. This is called the 100-feet raised beach, and is an important landmark. It is very conspicuous at Bo'ness, Rosyth, and also in the Edinburgh district, and at Larbert and Stenhousemuir there is a wide plain of sand and gravel along the Carron Valley at the same level, on which the famous Falkirk Cattle Trysts are held every year. (See section p. 107.)

So far as I have been able to ascertain after many years of investigation, there is not a particle of evidence in the Forth Valley that the sea after the glacial period ever reached a higher level than this. Although at other parts of the country there may be evidences of marine erosion at a greater height, there are none in this district, and the 100-feet beach appears to mark the high-water line reached by the sea after the great submergence which followed the Ice Age.

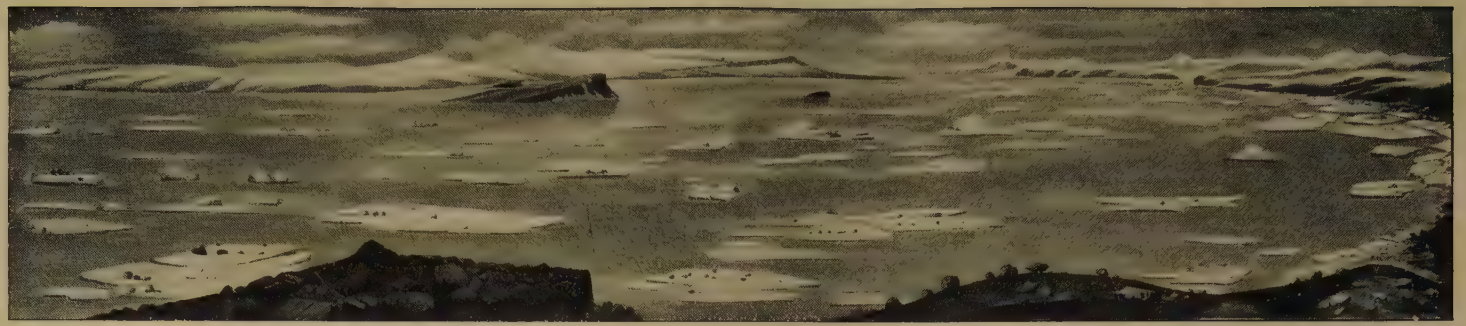
At that time the Forth Valley was under water all the way up to Aberfoyle and almost as far as the foot of the Ben Lomond ridge. Loch Lomond was likewise an arm of the sea, and Dumbarton Rock a solitary island in a great lake which overspread the site of Glasgow and the Clyde Valley. The old Firth of Forth had fewer islands then than now, but the top of Inchkeith was above water, and the Ferry Hill at North Queensferry was cut off from Fife by a narrow

sound at Inverkeithing. The bold escarpments of Stirling Castle, and the Abbey Craig and the tip of Craig Forth, rose in solitary state through the dark and icy water. I have in the sketch on the opposite page attempted to give an idea of the probable appearance of the valley, as seen from the Abbey Craig, when the sea was full of floating ice and when glaciers came down from the distant glens near Ben Ledi and Ben Lomond and broke into bergs on the frozen strand.[1] The appended map shows the respective areas of land and water in the Forth and Clyde basins at the time of the greatest submergence.

The End of the Ice Age.—The ice melted at last, and trees began to grow on the old moraines and "drums" or ridges of stony till that covered the land. At the same time the sea began to recede, but not at first to its existing level. There were pauses in the movement of upheaval, and these were marked by the formation of raised beaches at lower levels. At some places there is a terrace at about 50 feet above sea-level, but this is not very conspicuous in the estuary. The most important pause in the uplift was the last, when for a long interval the sea stood at about 20 to 25 feet above ordnance datum, or about 10 feet over the level of the ordinary spring tides of our day. This was the time when the rich alluvial mud of the Carse was precipitated, which covers all the flat land from Bo'ness to Stirling and Aberfoyle.

The Carse clay is blue or greenish in colour, and is full of organic remains betokening a long spell of mild weather. Shells, sticks, and whole skeletons of whales and seals are to be found in it. In the Carnock pit near Dunmore, which was sunk through these post-glacial deposits to the rock in 1903, the following interesting section was revealed. The surface of the ground is 48 feet above ordnance datum at the place, showing that the sea had not yet retired to the 25-feet level, but was practically at the 50-feet beach stage when the highest of these beds was laid down.

[1] The lower panorama, introduced again for the sake of comparison, is the same as that shown at page 90.



The scene at the end of the Ice Age when the valley was submerged under an icy sea.

The modern landscape after the sea had retreated to its present level.

PANORAMAS FROM THE ABBEY CRAIG AT STIRLING AT DIFFERENT PERIODS IN THE HISTORY OF THE FORTH.

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CARNOCK PIT SECTION.

	Feet.	Inches.
Surface soil	0	9
Clay	6	6
Silt	7	9
Blue clay	3	6
Peat moss with a bed of hazel nuts	2	0
Blue clay	4	0
Red clay with sand	2	6
Mud	3	0
Hard boulder clay	7	0
	37	0

The peat found at 20 feet below the surface was situated about 20 feet above mean sea-level. It contained a remarkable bed of hazel nuts at Carnock, and was also got in Polmaise Colliery sinkings at two separate collieries, respectively 3 and 4½ miles nearer Stirling.

In Nos. 1 and 2 of the Polmaise pits, situated at Kerse Mills, 1½ miles east of Stirling, the following section was met with :—

	Feet.	Inches.
Soil	1	6
Yellow clay	3	6
Blue silt (Carse clay)	21	0
Peat	0	6
Fine sand with water	12	0
Coarse sand with shells	0	6
Red clay with stones	4	6
Red clay	36	6
Sand, gravel, and boulders	19	0
Depth to rock	99	0

The surface is here about 41 feet above mean sea-level, so that the peat bed 26 feet down the section is 15 feet above ordnance datum.

A bed of peat about the same height above sea-level and 19½ feet below the surface was also found in one of the bores at Alva made in 1826 in the Devon Valley. Dr. Peach tells me that he once found a peat bed exposed in the Carse in the bank of the Allan Water below

Bridge of Allan which contained twigs with oyster shells attached to them, showing that the land and woods on it had suddenly sunk into clear sea water where oysters were flourishing.[1] This proves that the movement of upheaval was not continuous. After the red clay was laid down the climate changed, and blue clay or mud was deposited on it at Carnock to a depth of four feet. There must have been a long pause while the blue clay remained above sea-level as a wide expanse of low land overspread with a peat moss. The bog extended for miles up the valley, and was covered with copsewood or dense forests of hazel and other trees. The land then subsided for a time to a depth of at least 20 feet below the sea to permit of the peat mosses and woods being buried under the upper beds of the clay and silt. It finally rose again to its existing level, pausing during the time of the 25-feet beach.

It is generally an easy enough matter to trace the signs of upheaval of land, but clear proofs of subsidence are not so common. Apart from such pieces of local evidence, we might quite fairly have concluded from superficial observations at other parts of the estuary that the land rose continuously out of the sea, by a series of successive upheavals, marked by a regular succession of raised beaches, or steps. In reality the postglacial movements were more complex, and included at least one of subsidence for 20 feet or more between the time of the 100-feet and the 25-feet beaches.

The 25-feet Beach.—The green and blue clay of the Carse is full of shells and organic remains, and when pits are sunk through it a very strong, fetid odour is given forth. The skeletons of numerous large whales and seals have been found in it at shallow depths in the Stirling district. The latest of such discoveries was made in the Grangemouth Dock excavations when several vertebrae were dug up about the year

[1] At Largo Bay remains of a submerged forest can be seen at low tide, and Mr. Milne Home says in his book on the Firth of Forth, at p. 22, that he excavated part of a root "with young mussels under part of it." This may be the outcrop of the same old land surface locally submerged to a greater depth, from which the overlying clay has been all washed away by the sea down to low-water mark.

SUBSIDENCE MAP OF FORTH & CLYDE AREA

PERTH
ARGYLL
STIRLING
DUMBARTON
RENFREW
LINLITHGOW
EDINBURGH
KINROSS
FIFE
Ben Lui
Ben More
Stobinian
Ben Vorlich
Ben Lawers
Ben Lomond
Ben Venue
Ben Ledi
Ben Vane
Ben Cruachan
Ben Nevis
Ben Cleuch
Ben Chonzie
Ben Voirlich
Ben Chonzie
Ben Shalgairean
Ben Arthur
Ben Donich
Ben Lochy
Ben Blaich
Ben Mhor
Ben Mhurich
Ben Reoch
Ben Ime
Ben Narnain
Ben Bhreac
Ben Vorlich
Ben Ledi
Ben Venue
Ben Vane
Ben Lomond
Ben Cleuch
Ben Chonzie
Ben Voirlich
Ben Shalgairean
Ben Arthur
Ben Donich
Ben Lochy
Ben Blaich
Ben Mhor
Ben Mhurich
Ben Reoch
Ben Ime
Ben Narnain
Ben Bhreac
Loch Earn
Loch Lubnaig
Loch Katrine
Loch Voil
Loch Achray
Loch Venachar
Loch Lomond
Loch Long
Loch Goil
Loch Fyne
Loch Awe
Loch Leven
Loch Tay
Loch Rannoch
Loch Tummel
Loch Garry
Loch Ericht
Loch Laidon
Loch Rannoch
Loch Tummel
Loch Garry
Loch Ericht
Loch Laidon
Loch Leven
Loch Fyne
Loch Long
Loch Goil
Loch Lomond
Loch Awe
Loch Tay
Loch Katrine
Loch Voil
Loch Achray
Loch Venachar
Loch Lubnaig
Loch Earn

1900. The Carse clay spreads out over a wide area, and forms a rich, heavy subsoil, very suitable for the growth of such crops as wheat and beans. The Carse land begins at Bo'ness and extends to Falkirk, Grangemouth, Alloa and Stirling on the south side of the estuary. Beyond Stirling the same flat alluvial plain runs up the valley to Cardross, and forms the Vale of Menteith. As it is followed westward, however, it gradually rises from 25 feet till it reaches about 50 feet, in the Menteith district. All over the plain above Stirling and at Dunmore and other places there are still, or have been until recently, deep peat mosses of great size which have covered up the alluvium and prevented the rich land from being put to any good use. The profitable utilisation of these, and the reclamation and cultivation of the good land buried below, will be discussed in another chapter.

Expiring Glaciers.—In the far north of Sutherland at the head of Loch Eriboll and elsewhere, we find evidence that the valley glaciers still reached down to sea-level at the time of the 50-feet beach, although in the Forth Valley they had apparently all disappeared into the remote glens by that time. In the high ground of the Arrochar highlands the marks of the last glaciers are abundant. The country north of Loch Sloy is dotted over with moraine mounds, some of which are shown in the accompanying sketch. These are heaps of rubbish and stones which fell from the higher cliffs on to the valley glaciers, and were carried down and dropped over the end of the melting ice in irregular banks and knolls. (See next page.)

Kames.—But the larger glaciers also spread their marks over the low country far from the mountains. As the great ice-sheet melted away and gradually vanished off the face of the Lowlands it dropped quantities of loose stones on to the top of the hard till which lay below. Besides these travelled boulders, some of which are very large, we find mounds of gravel called *Kames* scattered over many parts of the low country. These have been apparently produced by streams of water on the top of the melting ice or more likely under it, which washed away the stones and sand, and dropped them continuously

over the edge after the manner of moraines. Here, however, the materials contain more sand and are fine in grain, water worn and more or less stratified. All over the valley round Linlithgow and in the neighbourhood of Polmont these sand and gravel mounds are very conspicuous. One remarkable gravel kame, about 30 feet high, runs for three miles like a railway embankment with a few interruptions from Callendar near Falkirk to Polmont, about 250 feet above sea-level, and loses itself among the rounded hills of gravel which are spread over the Avon Valley to the west of Linlithgow. These sand and gravel mounds are not found above the 250-feet contour level in this district, and thus it is evident that the expiring glacier lay in the Linlithgow Valley to at least that height at the time when they were produced. They could not have been deposited in a loch by ordinary running water, as they are isolated or in groups which have evidently been dumped down where they lie. The large glacier may have melted away irregularly in lumps with hollows between them. Into these the water running off its surface collected in temporary pools, and washed in the grains of sand as they gradually emerged through the surface of the disappearing ice. There may also have been tunnels under the ice in which the water swept along shoals of gravel from the melting glacier. The gravel mounds extend eastwards from Linlithgow to the neighbourhood of Binns and Blackness, where they thin out and disappear. It seems clear that a separate part of the great ice-sheet lay here for a long time on its deathbed, and since then no more ice came back to disturb the deposits bequeathed to the district by the dying giant.

But the glacier did not disappear without leaving other important effects behind it. As has been stated in a former chapter, there can be little doubt that the original course of the consequent River Avon ran, like that of the other tributaries of the Forth, in a north-east direction to join the main valley between Binns Hill and Blackness. As the ice retired, however, it left this part of the valley so blocked up with detritus and boulder clay that the river, when the ice melted

BEN VORLICH. LOCH SLOY. BEN VANE.

The Stony Mounds in the foreground are the Moraines left by the last of the Valley Glaciers.

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away, could not find out its old mouth. There was but a low ridge between the Forth and the Avon to the west of Linlithgow. Here the great glacier had, no doubt, worn down the soft rocks considerably, during the Ice Age, and the river thus found that its easiest way of escape to the Forth was to overflow in a north-westerly direction across the ridge. This is, I believe, why the Avon, instead of running straight along the valley towards Blackness, forms a singular exception to the other Forth tributaries on the south shore, and turns sharply to the left at Linlithgow Bridge, entering the sea through a narrow gorge running in a north-westerly direction to Inveravon. This little glen, 2½ miles long, has thus been excavated since the time of the great glacier, and is to be considered as postglacial in age.

A considerable number of bores have been made between Linlithgow and Blackness, in all of which a great depth of boulder clay and gravel has been disclosed. If this were to be swept off the rock, the old valley would, no doubt, be distinctly traceable all the way from Linlithgow Loch to Blackness. One of these bores was made half a mile south of Blackness on the 100 feet contour line, and the depth to the rock was found to be 155 feet, showing that there is here an old buried river valley 55 feet below sea-level which, I believe, can be no other than the continuation of the preglacial Avon.

Old Lakes.—The debris was not emptied down continuously, but in great heaps with hollows between them, some large and some small. One of these hollows became Linlithgow Loch, which is surrounded by gravel hills. It is smaller now than it was even in historic times, as the outflowing stream, which falls into the Avon at Little Mill, has washed away the gravel barrier on the west, and so lowered the outlet. The process has been arrested by a sluice which now holds the water impounded at a permanent level.

This brings us to the question of the old lakes that were produced, not by the excavation of the rock, but by the unequal distribution of the drift which was left scattered over the country by the retiring glaciers. The largest in the Forth Valley is the Lake of

Menteith in the low ground at the edge of the Carse. There were hundreds in the Lothians and Fife, but they were mostly very shallow, and they have nearly all disappeared in historic times by draining and agricultural operations. No doubt a little investigation might disclose the sites of a great many which have long been forgotten but were of some historic importance to lake dwellers and other natives of the country in the prehistoric ages.

Some years ago I collected evidence relating to the old lochs of the Edinburgh district, and as that subject is relevant to the discussion of the effects of the Ice Age, and of interest to local antiquarians and geographers, the substance of the investigation has been reproduced in the next chapter.

The Human Period.—We now come to the interesting transition stage when the geological record merges into that of human history. It is not easy to define the exact point where geology ends and history begins, as the forces of nature, apart from the influence of man, are still at work modifying the physical geography of the Forth Valley. The fact is that the one record overlaps the other at every point, and man himself becomes a geological agent producing physical changes on the earth's surface in a comparatively short space of time that would take many thousands of years to carry out if left to the unaided forces of nature. Some of these will be discussed afterwards, but in the meantime it may be of interest to look into the question of the first appearance of man in the Forth Valley, so far as records of his presence have been left here. Was man here at the time of the 25-feet beach when the Carse clay was laid down, and did he sail his rude boat over the arm of the sea that stretched far up the valley beyond Stirling to the Menteith hills? Have we any means of finding out how long ago the last uplift took place, or whether the land is still rising or subsiding in the Forth Valley?

For the information of those who are not archaeologists it may be mentioned that two kinds of stone implements are found in some caves and river gravels—the palaeolithic or chipped stone implements,

and the neolithic or polished stone implements. The men who used the former are believed to be the older race who were in Britain before the end of the Ice Age, and when the cold became severe it is supposed they were driven south to warmer parts of Europe, where they sojourned for some generations and received a foreign education.

There are, however, no palaeolithic remains to be found in the Forth Valley, and the oldest implements which have been discovered are of the polished or neolithic variety.

Early Human Remains.—The occurrence of skeletons of whales and seals in the Carse clay has already been referred to. In 1819 the bones of an immense whale, 70 feet long, were found under the north-east slope of the Abbey Craig in the blue slit 22 feet above high-water mark on Aithrey estate, 1½ miles from the Forth. Near the whale two pieces of stag's horn were found, through which a hole had been bored. Another interesting discovery of the same kind was made in the Carse clay under the Blairdrummond Moss. Mr. Milne Home, in his book on the Firth of Forth, at page 21, gives some interesting details of this discovery. The section at the place, which was 30 feet above high-water mark, was as follows:

Peat moss (removed in the reclamation),	12 to 13 feet.
Carse clay and shell bed at bottom,	4 feet.
Bones of whale embedded in the clay.	
Peat moss (immediately under skeleton), penetrated with roots of equisetum and containing trunks of trees, alder, etc.,	6 feet.
Bluish sandy bed.	

With the bones of the whale there was discovered a piece of a stag's horn similar to that found with the Aithrey whale. A round hole had been bored in it into which a piece of wood was fitted. Now both these cases prove clearly that human beings were there to hunt the whales when the Carse land was under water. The bed of peat under the Blairdrummond whale is apparently the same as the

one previously referred to as proving a subsidence before the 25-feet beach period. It therefore appears that men were in the district at the time of the submergence, which, as we have seen, carried the old land surface down below sea-level and allowed oysters and mussels to breed on the drowned forests before they were buried under the Carse clay. The upheaval that lifted the Carse clay to the level of the 25-feet beach was thus a later event, which must have given our rude ancestors much concern, but while it diminished their sea and loch fishings it also increased the size of their hunting grounds, and they thus had, probably, not much to complain of in the end.

Date of the Last Uplift.—When did this last uplift take place? All we can say with certainty is that it was some time before the arrival of the Romans. This is proved by the position of several Roman works near the shore.

At Bridgeness a discovery was made in 1868 of a remarkably fine Roman legionary tablet apparently marking the hitherto doubtful position of the eastern end of the wall of Antoninus. The stone, a drawing of which from a photograph is here reproduced, was about nine feet long. It was found lying face down on the promontory of whinstone at a point 19 feet above the level of ordinary spring tides. The stone, which I saw lifted up from its resting-place on the day it was found, was lying face down, not flat on the ground, but over a hollow in the soil, and it had evidently been carefully laid there and covered up with a few inches of soil. This was probably done for the sake of protection by the Romans themselves before they left the country, as perhaps they intended to come back and set it up again. It is the reverse of probable that it had been so laid down by the ancient inhabitants, who would have no love for the memorials of the great invasion. The tablet was lying on about three feet of unstratified forced soil, resting on the whinstone of the Bridgeness promontory, and it was clear it had never been reached by the sea since it was left there. Close to this spot an old dry-stone dyke of squared freestone such as the Romans

THE ROMAN LEGIONARY TABLET FOUND AT BRIDGENESS IN 1868.

The squared stones under the Tablet were taken from the Roman sea dyke discovered near it, and the photograph was made while the Tablet was temporarily set up in the old Grange garden before it was presented by the late Mr. Henry Cadell of Grange to the Antiquarian Museum in Edinburgh.

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used in constructing their permanent camps was found, extending for a few feet like a rough retaining wall round the face of the promontory about five or six feet below the flat ground under the tablet. This building, evidently Roman, had likewise never been reached by the sea, as it would not have withstood the waves of a single gale.

We are thus left to conclude that the sea never came up to within six feet of the stone. As it was lying 19 feet above high tide level, it is clear that there cannot have been a rise of so much as 13 feet since the Roman occupation, if there was indeed any elevation of the land at all.

There is, however, evidence from other places that the Carse land of the 25-feet beach was in existence in the Roman period. During the reclamation of the Blairdrummond Moss described in Chapter XIV., the deep bog was found to contain a forest which had been felled by the Romans in order, no doubt, to deprive the hostile natives of the shelter which the trees afforded. Roman implements and vessels were found among the fallen stems, and the traces of a military road were found leading across the Forth Valley. One of these trees had rings showing it to be over 314 years old, but others were much older. The Roman road was probably made across the valley by Agricola about 81 A.D., so that the forest was growing in 233 B.C. The sea cannot therefore have been over that part of the Carse which is now 30 feet above high tide level for 2146 years, and probably a few centuries earlier, as this was not the oldest tree discovered under the peat. The Carse, or at least the higher parts of it, must thus have been dry land at the time. While it is thus quite certain that the sea has not retreated as much as 25 feet, it would be rash to assert that there has been no elevation of the land at all during the last 2000 years. There is room for a few feet of a rise, no doubt, but all the evidence shows that the upward movement, if it had not ceased altogether, was very nearly over when the Romans first came into the Forth Valley.

CHAPTER VIII.

THE OLD LOCHS OF EDINBURGH.[1]

WHEN the glaciers of the Ice Age finally melted away, they left the face of the land sprinkled over with multitudes of shallow pools and deep basins of water both in the highland glens and the lowland districts. The smaller and shallower lochs have all diminished in size as centuries have rolled past, or have entirely disappeared in many places. But their vestiges have often been left behind, and can still be traced with accuracy, particularly at those spots where excavations for drains, and other works, have been carried on, and where archaeological or later historical evidence comes to the aid of the geologist.

The Edinburgh district is one of these places. Many examples of former pools and lochs are to be found amid the hills and dales of the modern Athens. Some of these are entirely prehistoric, but others have been reclaimed or drained within the human period. Others again still exist but in a diminished condition, and it is of interest to collect such evidence as has been discovered from time to time, and endeavour to make an outline of the picture it discloses. Edinburgh has lost something with the disappearance of these ancient lochs, no doubt, although more building land has been thus acquired. The map that I have compiled may help to convey some impression of the changes in the district since the waters

[1] The substance of this chapter originally appeared under the title "Some Ancient Landmarks of Midlothian," in the *Scottish Geographical Magazine* for June, 1893.

prevailed, and the evidence for these changes we shall now proceed to discuss.

The oldest reliable map of Midlothian seems to be that of Timothy Pont, published during the reign of James VI., before 1625. Since that time the face of the country has undergone many alterations. Wide expanses of peat-moss have been reclaimed, forests have been cleared away, and barren moorlands have been drained and converted into smiling meadows or tracts of rich agricultural land.

The time of which I wish now to speak, however, goes much further back than that of the Union of the Crowns, and even antedates the period of the Roman invasion. The 25-feet beach was the sea margin then, and the extent of the land that has since emerged may be seen from the map of the old lochs (page 142). The population of Scotland was then insignificant, and our savage ancestors were too few and too ignorant of the arts of peace to exert any important influence on the external appearance of Caledonia, the greater part of which remained a land of brown heath and shaggy wood until a much later period. All the changes that then took place were brought about by the slow agencies of Nature, which have, ever since time began, continued to wear down, level up, and smooth over the natural roughnesses of the rocky crust we live on.

Could one of the old residenters of 3000 years ago return and give us the benefit of his impressions about the principal changes in the face of the Edinburgh district since his day, he would no doubt, in the first place, note the disappearance of several conspicuous sheets of water from the neighbourhood. He would next sigh for the ancient forest of Drumsheugh, where he was wont to chase the wild boar, deer, and wolf, and he would probably be much astonished, on going down to the Firth of Forth at Cramond, Leith, or Portobello, to find that the sea had gone back permanently several hundred yards, leaving exposed broad tracts of sandy foreshore over which he had in his youth paddled his coracle at the lowest tides in search of fish or oyster beds.

The disappearance or notable diminution of the ancient lochs in the Edinburgh district is a subject of much local geographical interest, and I shall now endeavour to examine some of the evidence on which their former existence is inferred, and show on what principles the accompanying prehistoric map of the district has been constructed.

It requires but little reflection to arrive at the conclusion that lakes are, geologically speaking, one of the most evanescent features in the scenery of a country. The reasons for this are mainly twofold.

In the first place, most lakes, and indeed all the lakes in our latitude, have an outflowing stream to carry off their superfluous waters. Running water has a strong tendency to wear down the bed of the channel over which it flows. If it is clear and free from sediment, this tendency is not always very pronounced, as it is the hard particles in the river that do most of the grinding of the rock below, and the friction of pure water alone is geologically of little importance. Where, however, the effluent stream falls over rapids or rocky barriers of varying hardness, waterfalls are formed which constantly eat their way backward towards the sources of the river. In this way the exquisitely clear, green waters of the Niagara are steadily eating the falls back towards Lake Erie, and the equally pure river of the Yellowstone is excavating its magnificent falls and pushing them up the cañon towards the noble lake in the plateau above. The final result of this process is the drainage of the parts of the lake above the level of the outlet.

But this is not the main cause of the temporary character of lakes. It is not so much the outlets as the feeders that sow the seeds of their decline and death. Lakes act the part of filters to the rivers that flow through them, and as filters become choked up and useless after a time, so do these great natural strainers become choked with the sediment that is constantly poured into them. Sediment can only be carried in water which is moving at a certain rate, and as the force of the current diminishes, the suspended particles begin to sink to the bottom—the coarser first,

and the finer grains afterwards. Every stream that enters a lake brings down its quota of stones, sand, and mud, and drops them as it enters the quiet water, which thus acts as a natural filter. In this way sediment constantly accumulates in the basin of the lake, and the water that issues at its lower end is no longer turbid, but clear and limpid. An ordinary map of any of our Scottish lochs shows generally a tongue-like promontory at the mouth of each of the larger streams that feed it. There is, for example, a conspicuous projection of this kind at Lower Inveruglas, where the Douglas Water enters the west side of Loch Lomond, and another at Ardgarten, where the water from Glen Croe is discharged into Loch Long. If, as is usual, the largest feeder flowing down the main valley enters at the head of the loch, the mouth of the stream is generally found to meander sluggishly over a flat plain, partly meadow and partly marsh, liable to frequent inundation. The Dochart and Lochy, for instance, enter Loch Tay through a plain which, on a geological map, would appear as alluvium swept down and deposited in the form of a delta at the mouth of the river. A stream entering a narrow lake at one side is generally seen to shoot out a fan-shaped delta, which, if the amount of material transported from the higher ground be large, sometimes extends right across the valley so as to form an embankment which cuts the basin into two parts. A well-known example of this phenomenon occurs in Switzerland, where the town of Interlaken, as its name implies, stands between the lakes of Thun and Brienz on a broad bank of alluvium discharged by two rivers from nearly opposite sides of the valley into what was originally a single long lake basin. Another and perhaps more familiar instance of this bisection and subdivision of a narrow loch by the agency of lateral feeders is to be found in Strathyre, which was once occupied by a single long tortuous sheet of water stretching all the way from its outlet at the Pass of Leny to the foot of the Braes of Balquhidder, and which is now represented by the three basins of Loch Lubnaig, Loch Voil, and Loch Doine—

detached basins differing but slightly in level, and separated by alluvial haughs or fans spread out by the torrents from the adjoining mountain slopes. Many of our smaller Highland lochs have in this way completely disappeared from the landscape, and are now represented by flat alluvial meadows or haugh lands, through which the river winds peacefully, carrying down materials to fill up the next basin that may present a convenient "free toom" for its waste products.

If all our lakes are thus diminishing in size, it is clear that at some future date they will become entirely obliterated, and the geologist of the future will only be able to infer their former existence by such evidence as he can collect either from human records or from physical data.

It is by reasoning in this way that we are able to infer the former existence of several important sheets of water in and around what is now the site of Edinburgh, some of which are still represented by smaller lake basins, while others have disappeared within historic times, and a few have ceased to be remembered even in the traditions of the remote past.

During the long continental period before the Great Ice Age, when the British area was still a part of the mainland of Europe, any lakes which may have been previously in existence were no doubt completely obliterated. Our mountains and valleys were at that time all in existence, but no sparkling lochs lighted up the landscape. The rivers hurried down from their mountain cradles through deep glens, sweeping their load of sediment away to the distant sea without ever meeting a temporary asylum wherein to rest and wash off the stains of their weary pilgrimage. When the vast glaciers of the Pleistocene age, after hugging the land in their long, rude embrace, at last melted away, they left the whole face of the land sprinkled over with multitudes of sparkling pools and freshly cut rock basins in the bosom of the hills. Most of the lochs in the Lowlands were formed by dams of detritus or hollows in the surface of the glacial drift; and as time went on, these, being chiefly shallow, were

the first to disappear. The brooks that fed them brought in quantities of stones, sand, and mud from the higher grounds, as well as twigs and leaves from the forests that clothed their banks. In this way most of the lowland lakes were gradually silted up, and eventually a dense growth of pulpy peat not infrequently overspread their sites and gave rise to swampy bogs and quaking flow-mosses that continued to flourish for many centuries. At places where the water remained clear for lengthened periods, molluscs lived for ages, and their delicate shells accumulated in myriads upon the oozy floor. As time went on, beds of white calcareous shell marl were thus built up, and the presence of this characteristic deposit is one of the best evidences of the former existence of a lake at any place. When we find a smooth, flat hollow, surrounded by higher ground, and showing free, loamy soil devoid of stones of any large size, and, perhaps, a sluggish stream creeping softly across it, there is good reason to infer the presence of an old lake. If, moreover, on digging a few feet beneath the surface, we come on beds of peat, silt, laminated clay, gravel, fine sand, or shell marl, this inference is proved to be correct, and all doubt is removed as to the lacustrine history of the place.

From all the evidence, both historic and geological, we can now clearly demonstrate the former existence of seven more or less conspicuous sheets of water in the neighbourhood of Edinburgh. These "seven eyes" of ancient Dun Edin were as follows:

1. Gogar Loch.
2. Corstorphine Loch.
3. Craigcrook Loch.
4. The Burgh Loch.
5. Holyrood Loch.
6. Lochend Loch.
7. Duddingston Loch.

Of these only three are now represented by sheets of water, namely, the lochs of Craigcrook, Lochend, and Duddingston. There were in

addition several smaller pools or "dubs," which hardly deserved the name of lakes, situated at Canonmills, Morningside, the north-east of Blackford Hill, Hailes Quarry, and perhaps also in Hunter's Bog, between Arthur's Seat and Salisbury Crags. It may be remarked by readers acquainted with Old Edinburgh that the Nor' Loch is not included in the list; but there is no evidence that this lake had any existence prior to the year 1450. Like St. Margaret's and Dunsappie in the King's Park, it was of artificial origin. The valley north of the city, in the reign of David II., who flourished in 1144, formed part of the king's gardens, and was used for tournaments, sports, and military parades. In 1450 a dam was thrown across it, and the waters of the little stream issuing partly from the spring at the Well-house Tower, and partly from the rising ground to the west, was impounded to save the expense of building a wall along the north side of the city. The Nor' Loch existed for three centuries, the outlet on the site of the present Waverley Station being regulated by a sluice. It latterly degenerated into a huge cesspool for the refuse and sewage of the New Town, and was drained about the end of last century, the last traces of the morass, along with other public nuisances in the vicinity, being removed in 1816 for the sake of the amenity of Princes Street.

1. Gogar Loch.

The configuration of the ground between Gogar Burn and Corstorphine points to the former existence of a shallow lake about $1\frac{1}{4}$ miles in length, stretching along the flat hollow north of, and roughly parallel to, the railway. There is not much historical or geological evidence from excavations as to this old lake. That it existed in historic times is, however, clear, as is shown on Pont's map, already referred to, and in John Adair's map of 1680. It is also indicated in John Elphinstone's map of the Lothians, published in 1744, a copy of which is in my possession. It cannot, within the last three centuries at all events, have been a lake of much note, and was probably

little more than a bog when these maps were made. Reference to the bogs and marshes in the meadows at Gogar is made in the narratives of Cromwell's and Leslie's marches in 1650; and in July 1661 James Forrester presented a petition to Parliament in which he complained that "the whole meadow ground and low-lying lands was undone by the overflowing of the Gogar-burne, and that, partly through the neglect of those who formerly were accustomed to cast and keep clear the ditches and stanks through which the water did naturally pass, and partly by the inbreaking of the said water in the lands of Redhewes." The Gogar Burn may at one time have flowed eastward along this hollow to join the Water of Leith at Coltbridge, and may in course of time have brought down so much mud as to fill up the west end of the lake, and then find a new outlet into the Almond on the west. The ground is, however, so flat that it is equally probable the stream may have merely overflowed into this depression, the main portion of the water escaping by its present course into the Almond. Pont's map shows the burn flowing northwards past the loch in this direction. On the third (1910) edition of the 1-inch Geological Survey map (sheet 32), the probable original area of this loch is marked as an alluvial plain; and this forms the basis on which I have reproduced the lake on the map accompanying this paper, and have shown the Gogar Burn flowing into its western end.

2. Corstorphine Loch.

The ancient loch of Corstorphine must have once been a feature of considerable importance in the landscape, as its existence is proved by both historical and geological evidence of a very conclusive kind. It seems to have been originally separated from Gogar Loch by a flat tongue or ridge of boulder clay, and to have extended for a distance of nearly three miles from the vicinity of Broomhouse to the present Haymarket goods station, the original margin coinciding almost exactly with the 150-foot contour line on the Ordnance map. Both

of these lakes are referred to in the *New Statistical Account of Scotland*, vol. i. p. 245, and are shown on the old maps of the district. Elphinstone's map shows that during the century preceding 1744 the area of water had become greatly diminished. The draining of Gogar Loch was carried out about 1766, as it is not shown on maps of later date; and Corstorphine Loch was partly drained and reclaimed in 1670, when the deep ditch known as the Stank was excavated along its northern side. The final reclamation was completed in 1837, when the Stank was deepened and enlarged to prevent any further flooding of the rich alluvial floor of this ancient lake. The Castle of Corstorphine was built on the neck of dry land between the two sheets of water, and for many centuries must have thus occupied a position of considerable strategical importance. The once celebrated Forresters, Lords of Corstorphine, to whom the castle belonged, are said to have brought their provisions by boat from Coltbridge; and it was their interest to prevent the lake from being drained so long as their enemies were to be kept at bay and the strength of the fortress maintained. Dr. Taylor, in his interesting little volume, *A Mid-Lothian Village*, says that sometimes the tongue of land between the two lochs was partly submerged, the passage across being maintained by a ferry; and there is a tradition that at no very remote date a beacon-light used to be fixed up on the gable end of Corstorphine Church to guide the benighted travellers safely across the dangerous morass.

The deep cuttings through the district in connection with the Water of Leith purification works, as well as some excavations during the construction of the Forth Bridge Railway, near Corstorphine station, have revealed many interesting sections of the deposits found in this old lake. The late Mr. James Bennie, of the Geological Survey, made a careful study of these and other old lacustrine deposits, and has given an account of them in the *Proceedings of the Royal Physical Society*, vol. x. p. 133. In a cutting 7 feet deep, on the farm of Broomhouse, for a culvert below the Forth Bridge Railway,

the subsoil was found to consist of lake silt and peat. The silt was, Mr. Bennie says, crowded with fresh-water shells and *ostracoda*, and the peat, being composed chiefly of the stems of aquatic plants, was essentially a water peat. The excavations for the Water of Leith purification works, in which large sewers were laid westwards from Coltbridge to Corstorphine and southwards across the bed of the lake towards Gorgie, revealed a well-marked series of beds of silt, laminated and brick clays, sand, gravel, and peat, as well as occasional marl deposits, which show clearly that for long ages after the Glacial period this remained a lake of considerable importance. The sediment which helped to fill it up was no doubt chiefly contributed by the Water of Leith, which crosses its eastern end between Gorgie and Coltbridge ; and it is probable, as the old maps indicate, that, being nearest the source of deposition, this end of the lake was the first to disappear. The lowering by natural erosion of the boulder-clay barrier across the outlet at Coltbridge would also diminish the level of the water, and aid the stream in obliterating this ancient landmark from the district.

3. Craigcrook Loch.

This lakelet, situated in the hollow at the foot of the eastern slope of Corstorphine Hill, north of Craigcrook Castle, is now represented by a small, reedy pool on the east side of the road from Ravelston to Cramond. So far as I have been able to learn, it is not referred to in any description of the locality. Had it ever been a lake of importance, reference would have been made to it in Wood's very accurate *History of Cramond Parish.* It is, however, marked on Pont's map, and the configuration of the ground shows it to have once covered a much larger area than that of its present insignificant representative. The lake was, I believe, drained by a culvert leading northwards to the low ground near Davidson's Mains, but the original outlet must have been the burn running eastwards along the hollow through Blackhall and past the north side of

Craigleith Quarry and Comely Bank to the Water of Leith. The road from Ravelston, referred to above, crosses part of the old lake bottom. The field adjoining is locally known, I believe, as the Marl Pits, and it gets its name from the deposit of shell marl found by digging a few feet deep in this flat ground, which on the map is included in the old lake area.

4. The Burgh Loch.

This sheet of water, which was in existence up to the beginning of this century, occupied the site of the present Meadows. There was once a tradition about a lake in the neighbourhood of the Cowgate called the South Loch; but this tradition seems to have been founded on no conclusive data, and Maitland, in his *History of Edinburgh*, published in 1753, seems to have made out that the South Loch and the Burgh Loch were one and the same lake. There may have been in prehistoric times a few marshy pools along the hollow of the Cowgate and Grassmarket; and, indeed, Mr. Bennie mentions the occurrence of a black mud, with some aquatic plant remains, revealed in cutting a sewer at Bristo Port; but such "dubs" were no doubt once abundant in the district, and do not deserve special mention here.

The Burgh Loch and its marl and peat beds have been described by Hugh Miller and other writers. The marl, which was at places three feet or more in thickness, contained abundance of the delicate shells of *Limnaea*, *Valvata*, and *Pisidium*, as well as occasional specimens of *Planorbis*, and several species of ostracods, most of which forms are abundant in the marl of the other old lakes of Edinburgh. A list of these by Mr. Thomas Scott is appended to Mr. Bennie's paper, already referred to. The water of this lake was once used for domestic purposes, and a windmill was erected to pump it for the use of the brewers of the Society established by James VI. in 1598. The draining of the loch was begun in the early years of the

seventeenth century. In 1722 it was let for £800 Scots on a fifty-seven years' lease to Thomas Hope of Rankeillour, who began to drain it more perfectly, and converted it into a marsh, with a walk round it. It remained, however, a morass till 1840, when the water was finally completely drawn off, and since the first walk was constructed has remained a public resort, formerly patronised by the wit, beauty, and fashion of the Modern Athens. The surface of the ancient lake-bed was, like that of the Nor' Loch, for many years used as a "free toom" for rubbish, so that it is now raised several feet above its original level, and the uninitiated may therefore at first sight have some difficulty in realising its ancient lacustrine character. Modern improvements have so modified its appearance and levels of the surrounding ground that it is somewhat difficult to picture to ourselves the position of the ancient outlet and the surplus water when the loch overflowed, as it occasionally did. The Burgh Loch is not shown in Pont's map, nor is there any indication of a stream in the neighbourhood; but any effluent there was probably found its way westwards, and escaped into the east end of the Corstorphine Loch in the vicinity of Dalry.

5. Holyrood Loch.

The greater part of this lake is unknown to history, and the evidence on which its former existence is based is principally geological. There is, however, some reference made in old descriptions of Holyrood to a lake or piece of marshy ground at the foot of Arthur's Seat, along the edge of the old Palace gardens; and from an entry in the Lord High Treasurer's accounts it appears that the "loch beside the Abbey" was drained some 400 years ago, in the time of James IV., as a site for a garden.

The ancient loch of Holyrood must have nearly all dried up and disappeared long before the Abbey was founded in the beginning of the twelfth century, as King David, the "sair sanct," was not likely

to choose a soft morass on which to erect such a noble edifice. The configuration of the ground shows that the Abbey and Palace are situated right in the middle of the original lake basin, which had a rudely triangular shape, the longest side stretching north-eastwards along the foot of Salisbury Crags to the vicinity of Spring Gardens for a distance of about two-thirds of a mile.

Numerous excavations have from time to time been made in this flat area, and have been described by Mr. Andrew Taylor[1] and Mr. John Henderson[2] in the *Transactions of the Edinburgh Geological Society*, and by Messrs. J. A. Johnston and J. Lindsay in the *Transactions of the Edinburgh Naturalists' Field Club*.[3] I have myself also had opportunities of examining some of these sections before they were covered up, and it would be difficult to get a better example of a typical lacustrine flat in any part of the Edinburgh district. The best sections were revealed in the bores and excavations for one of the large gasometers at the South Back of the Canongate. In one of these bores the following strata were pierced:

	Feet.	Inches.
Forced material at surface	3	2
Yellow clay	2	4
Peat	3	0
Marl	9	0
White and brown mud	2	6
Blue and red clay	1	9
Rough gravel	4	6
Clay and small stones	5	6
Blue clay	7	8
Depth to rock	39	5

In this section we have typical lake deposits to a depth of about 26 feet below the present surface, the lowest beds being probably glacial drift of more ancient origin.

The variable local character of these old lake beds was well shown in the deep excavation for the gasometer tank. A careful

[1] Vol. v. p. 44. [2] Vol. v. p. 407. Vol. ii. p. 135.

section was drawn by the engineer in charge of the work, a copy of which in my possession shows that the rock surface was covered by a bed of marl, varying in depth from about 2 to 5½ feet. This was overlaid by a bed of peat less than a foot in thickness, above which came a thick stratum of "till," or rough stony clay, probably washed down by torrents from the adjoining steep talus of Salisbury Crags. At the north-west side of the tank the till was covered by a second bed of marl, showing that the floods gave place to a drier period, in which the water remained sufficiently tranquil for the delicate molluscs to flourish in peace. This marl, however, only covered part of the area, and passed into a bed of gray and yellow sand, 3 to 4 feet deep, along the south-east side of the excavation. The whole was overlaid by a covering of vegetable mould 5 to 8 feet thick, the greatest depth of the whole section of lacustrine strata at the south-east side being about 34 feet.

In the beginning of 1887 a cutting several hundred yards in length was made for a sewer running north-eastwards from this point past the Palace gardens, in which a section at places 20 feet deep was laid bare. Mr. John Henderson, in his description of this cutting, states that the surface to a depth of about 6 feet consists of artificial deposits, with fragments of pottery, oyster shells, bones, etc., resting on brown, peaty clay about a foot in thickness. This bed passes down into peat, which has at places a depth of 18 inches, and all along the section rests on marl 1 to 2 feet thick. The lowest part of the section consists of brown and blue clay resting on loose clayey sand, which seems to have here formed the floor of the lake.

From these sections it is clear that the ancient loch of Holyrood had originally a depth of between 30 and 40 feet at places, and that after several vicissitudes in climate it became silted up with material brought down by streams from the adjacent high ground. One of these brooks probably ran northwards along the hollow encircling the base of Salisbury Crags along the line of the Queen's Drive, and a second entered from the west, carrying down the drainage of the

valley between the Castlehill and the Calton, afterwards partially occupied by the Nor' Loch. As the lake shallowed, the fauna which flourished in the deeper water was choked out, and the area became overgrown with peat, only a few pools remaining to mark the place in historic times. The peat was full of twigs of birch, hazel, and other trees, which no doubt at one time formed part of the thick forest of Drumsheugh, whose gnarled oaks and sombre pines once cast their dark shadows across the bosom of this ancient lake.

6. Lochend Loch.

Of all the old Edinburgh lakes this little one seems to have undergone least change since the earliest times. It has no streams of any consequence for feeders, and hence has not become silted up. The water seems to be derived chiefly from springs, and as such is clear and free from sediment. The outlet to the west is small, and although the level of the overflow may have been somewhat lowered, there is not much evidence of any considerable shrinkage in area.

7. Duddingston Loch.

Although still the largest of the Edinburgh lakes, Duddingston Loch covers but a fraction of its original area, and the merest tyro in field geology can see that about half of the present lake has recently degenerated into a reedy marsh, which will at no distant date gradually become dried up and disappear in the ordinary course of nature. The level of the water is but a few feet below the 150-feet contour line, and by following this line we can approximately trace out the ancient margin. As all skaters know, this loch is supplied principally by springs rising at the foot of the Hangman's Rock and the Girnal Crag, and the outlet passes south-eastwards into the Braid Burn near the railway station. The ancient lake probably extended over the whole of the flat depression between Duddingston and Inch

House; and although it is not certain that the slight knoll on which the old mansion-house stands was actually ever a complete island, as its name would imply, yet it may have been near enough the water in Celtic times to have been described by that common epithet.

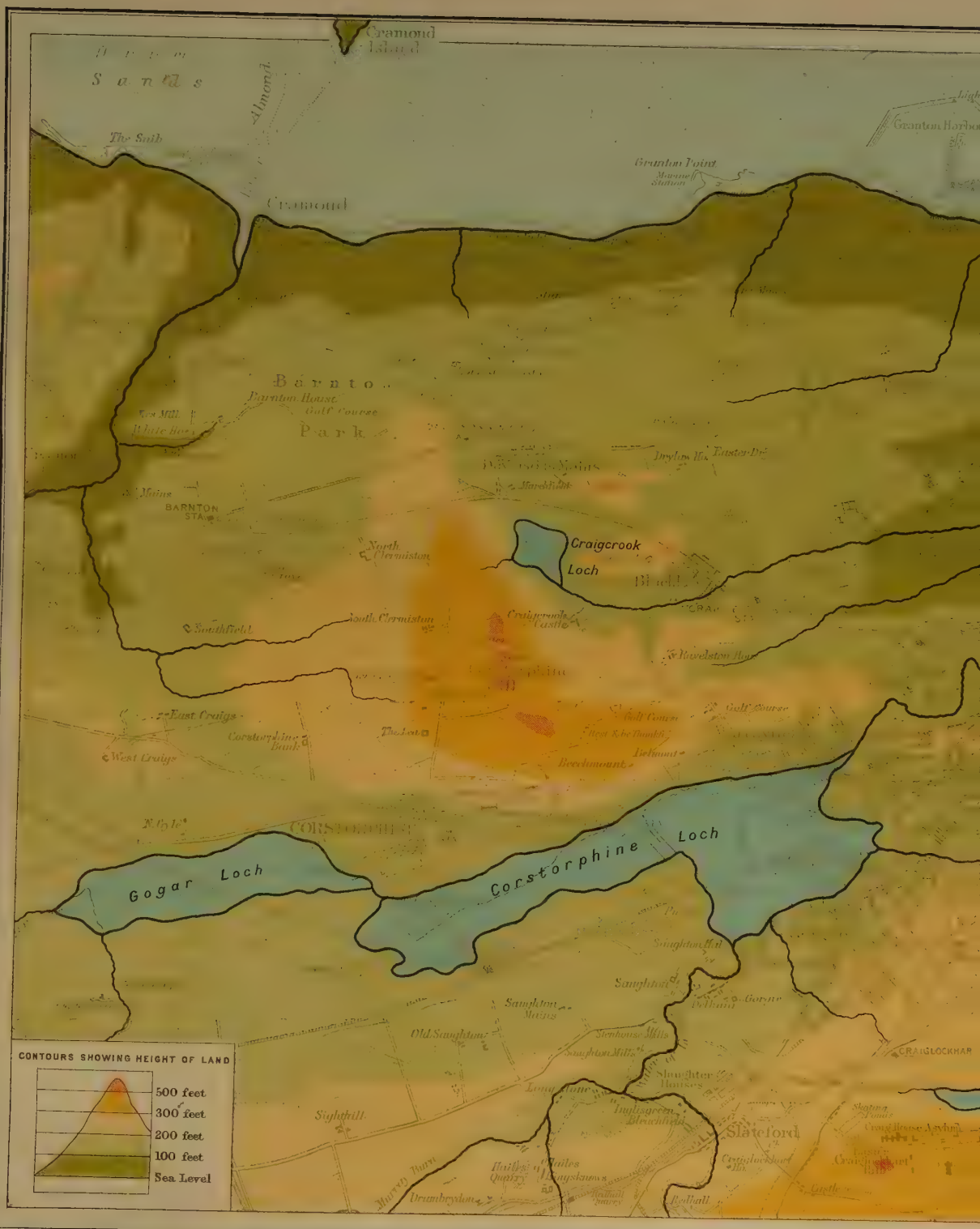
The ancient loch was supplied partly by the existing springs and partly by the waters of the Braid Burn and its tributary the Pow Burn, which join near Peffermill, and probably at first entered by separate mouths into the basin. These streams, in their original state before modern improvements had altered their courses and the character of the surrounding land, were no doubt subject to powerful spates. Large quantities of alluvium were swept down on these occasions from the high ground of the Braids and Blackford Hill, and deposited, where the current slackened, in the form of a flat delta at this end of the lake. Gradually the alluvial fan pushed back the water and spread over the greater part of the shallow basin, until at last this part of the depression was completely silted up, and the streams, uniting into one, parted company with their shrunken old friend the loch, and, passing it, left it to be maintained entirely by the springs and the rills from the adjacent slopes of Arthur's Seat. The southern part of the basin, whose total length at the end of the Ice Age apparently exceeded a mile, was probably shallow, and the silting-up was a comparatively rapid process, so that many centuries must have elapsed since the loch shrunk nearly to its present area. The deepening of the outlet by artificial means has no doubt helped further to reduce it within historic times. It would, however, be an advantage if the hand of man, instead of, as usual, assisting in the destructive work of nature, were to be employed in partially restoring the ancient majesty of this sheet of water, by clearing out the reeds and sedges by which it is nearly half occupied—a work which would be both patriotic and practical, and would, besides adding to the beauties of the district in summer, give additional room in winter for skating and the grand old Scottish game of curling.

Of the smaller pools or ponds in the district to which I have already alluded, the map shows two along the course of the Jordan Burn. One of these, which occupied the hollow south of Morningside Asylum, is represented by a well-marked series of lacustrine strata, exposed when the Suburban Railway cutting was made. Under the surface vegetable soil, which had a thickness of 2 feet, a bed of peat 3 feet thick was found resting on shell marl 2 to 3 feet in depth. The peat and marl extended along the cutting for nearly half-a-mile westwards from the Morningside Station to the point where the rock cutting begins at Myreside.

Another lakelet with a well-marked bed of marl existed at the foot of Blackford Hill, in the course of the Pow Burn, by which it was no doubt ultimately drained or filled up in prehistoric times. Canonmills Loch, again, was a pool connected with the Water of Leith, which occupied the hollow overlooked by the Royal Crescent. It is referred to in old maps and descriptions of Edinburgh, and was not completely removed till 1865, when the last part of it was drained during the construction of the Royal Gymnasium.

There were, no doubt, at the close of the Ice Age, other lakes of greater or lesser magnitude in the immediate vicinity of Edinburgh, one of which may have occupied the flat hollow along the Burdiehouse Burn, south of Craigmillar Castle: but I have no clear evidence in these cases, and as I have endeavoured to adhere to well-substantiated facts in tracing the outlines of the old lakes of Edinburgh, these must be left out of present consideration until further investigation shall have placed their origin quite beyond the region of doubt.

This, in conclusion, is a first attempt at the construction of a prehistoric map of the Edinburgh district, and no doubt contains many defects; but it may, I hope, serve not only to awaken interest, but also to incite to further investigations in that most fascinating field of research—the borderland between the past and the present—where the geographer and archaeologist step in and complete the tale of ages that the geologist has left unfinished.



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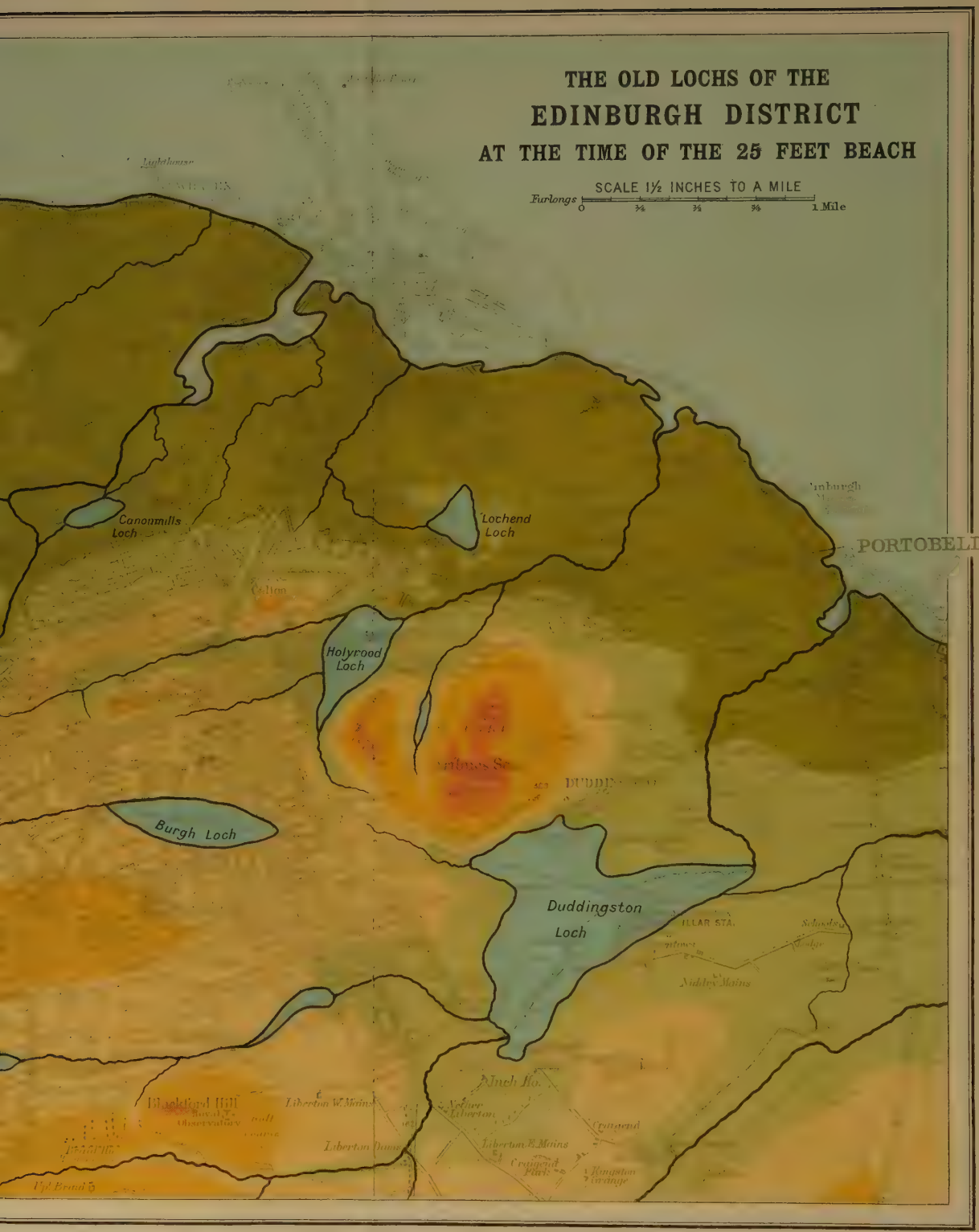

THE OLD LOCHS OF THE
EDINBURGH DISTRICT
AT THE TIME OF THE 25 FEET BEACH
SCALE 1½ INCHES TO A MILE
Furlongs
0
⅜
⅝
⅞
1 Mile
Canonmills Loch
Lochend Loch
PORTOBELLO
Holyrood Loch
Burgh Loch
Duddingston Loch
Blackford Hill
Observatory
Liberton W. Mains
Liberton Dams
Liberton E. Mains
Craigend
Craigend Park
Niddry Mains
Inch Ho.
J.G.Bartholomew

CHAPTER IX.

CARRON COMPANY AND THE RISE OF THE SCOTTISH IRON INDUSTRY.

THE Forth Valley, after its long and eventful curriculum in Nature's workshop, at last emerged from beneath the grinding glaciers and the icy seas into the sunshine of modern times, a finished product, shaped and ready for the human race.

Stored plentifully with useful minerals beneath and covered with good soil above, and designed by nature to be the home of multitudes of happy people, it lay fallow for many centuries, undeveloped and neglected, except by fierce factions and contending armies bent on the laudable work of driving out the invader or the less patriotic task of destroying one another. Famous in romance and history as the scene of many a bloody battle on land or sea, it remained a veritable valley of dry and broken bones until 1746, when the Second Battle of Falkirk closed the long and sanguinary record.

The "Auld Enemy" south of the Tweed had at last ceased from troubling, but the weary land, at rest from civil war, had not yet fully awakened to the advantages of the Union with England or the possibilities of a wider patriotism and a vast imperial expansion in territories across the sea. Scotland had indeed sunk into a miserable condition. The social life of the country in the first half of the eighteenth century has been depicted in deep enough colours by Henry Graham, and the perusal of his sombre tale is almost enough to make the Scot of the present day ashamed of his cherished

nationality. Poverty and stagnation were the national characteristics, with a profound and perhaps quite natural prejudice against everything and every person that came from England. Lethargy and stupidity reigned supreme. The Church was blighted by the chilling breath of Moderatism, and Scotland had hardly begun to develop the latent ability and force of character which afterwards made her a prosperous and useful member of the United Kingdom, and helped her to take a large part in building up the British Empire.

How and when did the national spirit awake, and our present-day wealth and prosperity arise?

One very modern school of economists, chiefly of the street-corner order, would have us believe that wealth is entirely the fruit of manual labour, but it needs little research to demonstrate the fallacy of this much-advertised doctrine. Scotland at that time was far richer in minerals than in our day, after the best coal and ironstone seams have been exhausted with 150 years of strenuous mining. When the Carron Company was projected the labourers were waiting in crowds, hungry and unemployed, able and anxious to work, but they did not know what to do or how to do it. The seams of coal and ironstone were lying almost intact, ready to be opened up on every side, and the demand for home-made iron was ever growing. But almost no iron was made and very little coal was raised, certainly was not for want of minerals or men to work them.

The oft-repeated assertion that labour alone is the source of all wealth is, in fact, one of these dangerous half-truths, the inculcation of which works immense mischief among unthinking minds. It is, indeed, not even a half-truth, but only a third. Two other factors are always required, as the following history clearly shows. These are CAPITAL and BRAINS, and the last is by far the most important of the three. Without the combination and co-operation of all these elements, the forces of labour must ever remain quite helpless. Water is made from hydrogen, no doubt, but only after it has first been mixed with oxygen in the right proportion, and even then it

will not produce the new substance. The transformation cannot be consummated until the indispensable spark of fiery energy is applied to the inert mixture. Like the dry bones of the Hebrew prophet's vision, the scattered units of unproductive labour must first be drawn together and clothed with the flesh and sinews of capital, and then quickened into life and activity by the application of brain power and the spirit of intelligent enterprise. This combination of *three* things must take place and be complete before the industrial army can arise in its might and march forth under able generalship to conquer the earth and make the desert blossom like the rose.

The dry bones in our dismal valley began, however, to shake mightily at last, and light to break forth in the latter half of the dark century. A new spirit was born in Scotland. Enterprising patriotic men, vexed at the backward state of their native land, hopeful men of the younger generation, who had been born with more than the average quantity of brains and energy, made their appearance in a few places. Some of them who had travelled abroad and gathered more ideas as well as gear than was common in those days, and what was more important still, who had overcome the national antipathy to the Southron, set themselves to devise plans for bettering the country by calling forth its latent resources and employing its idle inhabitants to the best advantage.

Dr. John Roebuck, the eminent scientist, and in later years the friend and helper of James Watt, although a native of Sheffield and an Englishman by birth, became by education and residence a naturalised Scot. He settled at Prestonpans in 1749, and applied his chemical knowledge to the manufacture of sulphuric acid. He there carried out, in partnership with Mr. Samuel Garbett, his invention of making the acid in leaden chambers such as have been used ever since in this important industry. Faujas St. Fond, who visited Prestonpans in 1784, says that this was the greatest manufactory of oil of vitriol in Britain at that date. The whole process was kept a profound secret and the plan wrapped in mystery, the works being surrounded

by very high walls, past which no stranger was allowed to go. While residing at Prestonpans, Dr. Roebuck made the acquaintance of Mr. William Cadell of Cockenzie, who owned ships and carried on a large trade, chiefly in iron and timber, with various European countries. Mr. Cadell thought that the iron, instead of being imported from Sweden and Russia, might very well be all manufactured at home from the native ore which was believed to exist in large quantities in Central Scotland. He communicated his idea to Dr. Roebuck and to his old friend, Mr. Samuel Garbett, a wealthy Birmingham merchant, who took up the proposal with enthusiasm, and the three happy companions at once proceeded to organise a company to carry out the project.

The voluminous correspondence in the writer's possession relating to the early years of Carron Company—the name given to the new firm—shows that the whole plan was very carefully thought out from the first. All arrangements were made and discussed in a thoroughly businesslike manner, with a view to large future expansion and the development of many subsidiary branches of local industry in the Forth Valley and surrounding districts.

Before a final decision as to the feasibility of the scheme and the situation of the proposed works could be reached, four cardinal points had first to be established. It was necessary: (1) To be sure of obtaining a sufficient supply of ironstone, and of charcoal to smelt it. (2) To find a place where adequate water power was available. (3) To be near the sea for the sake of transport, and (4) to secure a suitable site on a good tenure. All these matters were the subject of prolonged investigation and discussion during the spring and summer of 1759.

Mr. Cadell and his eldest son hunted about for ironstone along the shores of the Forth at Cramond, Bo'ness and elsewhere. Mr. William Cadell, jun., travelled for purposes of investigation about men and methods as far as Inveraray on Loch Fyne, where iron was being manufactured on the ancient system in the recently erected furnace

at Goatfield.[1] Craigforth, near Stirling, was also considered on account of its nearness to the Highland woods. A request was even made to consider the advantages of Sir Arch. Grant's estate of Monymusk in Aberdeenshire, where a certain quantity of ore and plenty of wood was available.

The best ironstone was, in the end, found much nearer home in the old coalfield of Borrowstounness (or Bo'ness), and in one letter we read that this discovery was regarded for the time as the sheet anchor of the whole scheme. It looked at first as if the best place for the works was to be on the Avon mouth at Jinkabout, a couple of miles west of Bo'ness, where the Duke of Hamilton had offered ground on favourable terms, but this site was finally abandoned in favour of the River Carron, which was nearer the Highland woods and had a better supply of water. Mr. Cadell was at first anxious to start the works on a more modest scale near his home in East Lothian, but he was overruled and gave up the idea in deference to the wishes of the other partners, who were supplying most of the capital and were firmly decided on the point.

The Carron Works were, it is to be noted, the first to use ironstone from the Carboniferous formation of Scotland. This mineral was found in strata associated with the coal, but had never been previously used for ironmaking. Only the poorer variety known as clay ironstone was, however, recognised at that time as an ore, and it occurred mainly in nodules or balls and thin lenticular beds in clay shale or blaes. The famous black-band ironstone, which made many a fortune in the nineteenth century, was only discovered by David Mushet in 1801.

Ancient Ironworks.—Iron had been made for centuries from hematite and brown ironstone in small quantities in the ancient

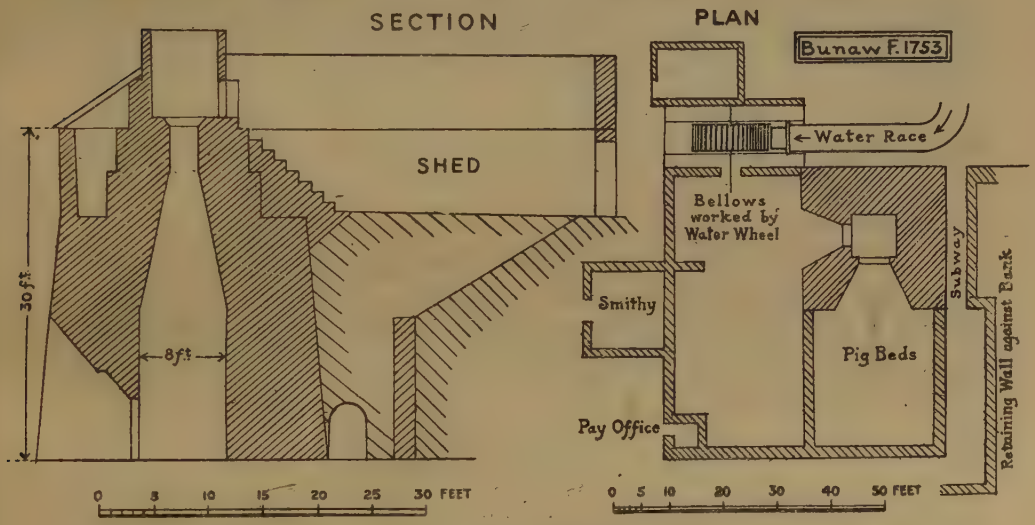
[1] This furnace was erected in 1754, and continued in operation till 1813, when the site of the works was used for a gunpowder factory that was wrecked by an explosion about 1885. The village of Cralecken or Goatfield was afterwards named Furnace, and is about eight miles below Inveraray. The ore was brought from Ulverston, and in 1788 the production of iron was 1400 tons. *Vide* W. Ivison Macadam on "The Ancient Iron Industry of Scotland," *Proc. Soc. of Antiquaries, Scot.*, Vol. XXI. 1887, p. 130.

bloomeries or little charcoal furnaces, whose abundant vestiges are to be found in the slag heaps in Argyllshire, on the shores of Loch Lomond, Loch Maree and other parts of the Highlands.

The Bonawe or Lorn Furnace.—The largest and most important of the old Highland ironworks, known as the Bonawe or Lorn Furnace, was erected near the mouth of the River Awe on the shore of Loch Etive, about ten minutes' walk from Taynuilt Station. Ironmaking in the district had been begun in 1730[1] by an Irish company whose furnace was near the mouth of Glen Kinglass, five miles further up Loch Etive. Its half-buried walls can still be seen, and heaps of slag with pieces of charcoal and red hematite of rich quality are scattered about the spot, while some of the pieces of pig-iron are still lying at the adjoining keeper's cottage of Ardmaddy on Loch Etive. This furnace was succeeded by that of the Lorn Furnace Company, which in 1752 took a lease of the land and woods at Bonawe, that ran for 110 years. The furnace, which is still in good preservation, bears the inscription "Bunaw F. 1753" on three cast-iron lintels, so that there can be no doubt when it was built. It continued in operation some years after the original lease expired, and did not finally cease working till about 1875. Several of the old furnacemen are still living in the vicinity who gave me their reminiscences when I visited the spot in August, 1912. Red hematite ore was brought by sea from Ulverston, and the finest quality of iron was produced, which was at one time sold for £26 a ton. Hundreds of people were employed in cutting wood and making charcoal on all the hills and in the glens for many miles around. There was also a great demand for oak bark for tanning, and this wood was barked before being made into charcoal, which gave additional employment for many years to a very poor but industrious population. When iron and bark fell each to £6 a ton, and to a still smaller price afterwards, and the hills were cleared of woods, the works had to be given up, and the worthy Bonawe Highlanders were unhappily deprived of their principal means of living.

[1] Ivison Macadam, *loc. cit.* p. 124.

The accompanying photograph and drawings which I have made show the general appearance and dimensions of this old building—the last survivor of the ancient charcoal furnaces of Caledonia. The furnace is 8 feet in diameter and 30 feet high, and is shaped like a round bottle with a neck 2 feet 6 inches wide, and a square top projecting through the roof of the shed, now used as a henhouse, that surrounds the charging eye. The mouth has become partly choked with rubbish at the neck, and on this an ash tree is now



growing vigorously, while another sturdy sapling is springing from the fern-covered wall outside. Thus we see how in the whirligig of time it has come about that trees are now living on the very furnace that once lived upon the trees. The original water wheel, to work the bellows for the blast, driven by a stream from the River Awe, is not in existence, but an iron wheel which was put in shortly before the works stopped, is the only part of the plant that remains. From the plan it will be observed that the pay office is only 4 feet square. There were no insurance stamps to lick in those days!

I have never seen an authentic drawing of any of the old charcoal furnaces, probably because none was ever made. I have therefore recorded these particulars for the benefit of the future historian of the old Scottish iron industry, before this interesting old structure has crumbled down like most of its early contemporaries, and disappeared for ever from the scene. The landscape showing Loch Etive and the smoke of the furnace when it was in full blast is from a drawing in the possession of the Rev. M. N. Munro of Taynuilt, who kindly gave me the benefit of his extensive local antiquarian knowledge, as well as a good photograph of the interesting sketch.

In such cases, before coal and coke were found suitable for iron smelting, the ironworks were located with reference not so much to the ore as to the fuel supply. The ore was taken to the fuel and not the fuel to the ore. So much charcoal was used that the wood supply was the prime factor to be considered, and the ancient iron smelters are probably largely to blame for the wholesale destruction of the old Caledonian forests. Scotland, and particularly the Highland part of it, is now, in spite of the poet's dictum, far from being a land of shaggy wood, and it has been left to the zealous arboriculturists of this generation to consider how best to restore its former shagginess and repair the damage done by the thoughtless old smelters.

The founders of Carron were, however, not so thoughtless in this respect as their predecessors, as the following letter, dated Birmingham, 16th June, 1759, from Mr. Garbett to Mr. Wm. Cadell, will show. In this letter a variety of important matters, including the general plan of the works, and land for tree planting, are discussed, and it is interesting otherwise as a record of the progress of the scheme at that date, before the site was definitely fixed and operations had begun :

" Dear Sir,

" Your much esteemed favour of the 31st Ulto. was not presented to me till last post,—I wrote You the 12th Inst., to which I beg your reference.

RUINS OF THE BONAWE OR LORNE FURNACE, 1912.

OLD PICTURE OF LOCH ETIVE

Showing the Village of Bonawe when the Furnace was working.

To face page 150.

"I should be glad to hear that Humbie is agreed with, as Spinnilford Mill on the Tyne from yours and Muckles account is well situated for Wood, Coal and Ironstone, even its distance from the Marquis of Tweedale's Woods is not near so far as Charcoal is carryed in our Country.

"From Muckles account of Spinnilford Water and the Water at Seaton Mill, the Latter is better than the former as the fall is so great, but I fear You cannot procure a Tack of Seaton Mills for 60 or 100 Years which I think is a necessary preliminary before We begin to build, as I remember it belongs to the York Building Company, and if so some months would unavoidably be lost before We could obtain any Certain Answer. Pray from whence doth the Water arise, If from a Coal pit Levell I suppose it will be a very constant and regular Stream, which is a Circumstance I should be glad to know, but cannot any future Proprietor or Worker of the Coals take the Stream from Us to answer purposes of his Own.

"Doctor Roebuck and I think Carron Water is a situation infinitely preferable to all others, because if the Works prove prosperous as We expect, some places in the Neighbourhood of the Firth of Forth will become one of the principal Seats of Iron works in Britain, not only for making Iron from the Ore into Barrs and Slit Iron, but into Nails and many other Manufactures; in all human probability this will be the Case. Under this Conviction it's undoubtedly right to begin our Works in a Situation that looks the most favourable for the Seat of such Manufactures and where our Works may be enlarged to a great Extent and notwithstanding continue Contiguous to one another, and in the Country that seems the most convenient for Manufacturers to settle, on account of its nearness to the Firth of Forth and its not being remote from Glasgow, and where exceeding fine Coal from Acton Boughey, Toryburn or Limekiln can be had always at a moderate expence, and not only Charcoal be delivered Cheap from the Highlands as

well as from Woods that are now near it, but the Land in the Neighbourhood of Carron might be rented on such Terms as to make it advisable to plant large Woods for the Supply of our Works.

"1 Furnace, 3 Forges, and a slitting Mill, would be a compleat Set of Works, and the Water of Carron is not only sufficient to supply such a Sett but is capable of supplying double that quantity, and it appeared to me that at a small expence we might be able to carry all our Iron &c from one Mill to another with Boats which is a very material consideration.

"We shall however chearfully join You in beginning a Furnace in your own Neighborhood, but we shall not be willing to leave the Water of Carron open for others to engage in, but shall probably soon make a beginning there, it would be Inconsistent with the sincere Affection and Esteem we bear you not to let You know Explicitly with the utmost frankness the true State of our Minds on the Subject for your Government, that you may consider whether it is not more prudent to make our first beginning upon the Spot where the Works will in all probability be Ultimately settled.

"Pray what doth the supply of Water at Spinnilford Mill depend upon, or is there *always* such a quantity running as was when Mr. Muckle took the measure, I mean is it a constant Stream of that Size which he mentions running day and night all the Year round. And is that what I am to understand from the Measures of all the Waters he hath sent Me.

"If We erect a Furnace at Seaton it will be so far from Lothian Woods that in all probability We must solely depend on Highland Woods. Probably three Forges and Slitting Mill might be erected on Brunstane water and at Musselburgh but then the Works would not be so Contiguous and Compact as on the Carron Water, nor could they be enlarged to 2 furnaces and 6 forges, and the carriage from one to another would be a considerable annual amount, and we could not plant Woods near our Works for our own supply, nor

could poor working Nail Makers fix themselves in E. Lothian so much to their Advantage and the Advantage of the Trade in every respect as they may between Lithgow and the Carron Water, and as it's plain to Us that if Works are begun on the Carron that neighbourhood will ultimately ding adventurers in E. Lothian We shall certainly soon engage that Water even tho' We begin one Furnace with you at Seaton or Spinnilford Mill which you please,—though we had rather go hand in hand with you to Carron and make a beginning at Stonehouse Mills tho' they are £76 a Year and We must probably give a Gratuity to gain possession. We would at the same time endeavour to secure every Mill upon the Water but let them continue grinding of Corn untill We wanted them for our own purposes.

"By all means let the Boro'ness Stratum of Ironstone be carefully examined. We must not depend upon any Bricks you can make to stand the Fire, nor do I find that it would be prudent even to depend upon Stourbridge Clay, I am in great hopes your Fire Stone will prove good and therefore wish to receive a Specimen of those sorts that You reckon the most famous.

"I think it would be better to defer the making of Bricks for the building untill We have fixed upon the Spot, if you determine upon Spinnelford Mill then begin the Bricks as soon as you please, and so likewise if you determine on Seaton, tho' I dont see how you can determine upon Seaton, as You cannot be certain of a Tack for a long Term of Years, and it would be madness to begin without. . . ."

But the obstacles that these pioneers of Scottish industry had first to overcome were immense. It is not easy for us, after a century and a half of steam power and other marvellous inventions, to picture the kind of conditions that obtained before any of these industrial discoveries had been made or peace was secured outside our borders and facilities for unrestricted commerce had been firmly established in the British islands.

A fierce struggle was going on in Europe, the Seven Years War was raging, and the fate of empires was trembling in the balance when Pitt became prime minister in 1757. We were then in the throes of a deadly conflict with France, but after three years the genius of the great statesman and the valour of our soldiers and sailors combined to raise Britain to the foremost place among the nations. The flag of empire was planted triumphantly by Clive in India and by Wolfe on the heights of Quebec, while Admiral Hawke destroyed the French fleet at Quiberon Bay off Bretagne in 1759. We were thus temporarily rid of a powerful foe, and the troubled land had a breathing space for peaceful development at home.

It is interesting to peruse the few fragments that have been preserved of the extensive correspondence of those stirring times that passed between Mr. Cadell and his friend Mr. Garbett. The latter had to leave his business for months at a time and serve his distressed country as a Militia officer.

On 14th July, 1759, he writes: "...On Wensday last the Warwickshire Militia reced. orders to be ready to march, and this day We receive orders to march on Wensday next to Salisbury... this nation is much threatened with an Invasion. We have upwards of 20,000 french Prisoners and no money would purchase foreign Troops to guard them, is not the militia of great use in that respect and are not the Gentlemen who have engaged in it Lovers of Liberty and their Country of course Friends to Mr. Pit and will give him weight in any Negotiation of A Peace...."

By August 7th he was in Camp at Salisbury, where he writes: "I am here experiencing the Life of a Soldier. I believe we shall not go into Camp, but guard some french Prisoners at this place. Our Battallion is so well disciplined that if the French Land in these parts We shall be orderd to join (what are called) the Regulars—We think Ourselves equal to any Troops that have not been in service—I can have Leave to go home whenever I please but I don't choose to ask at present. Dr. Roebuck hath had a Fever since I left

home but he is recovering fast, I suppose it will prevent his seeing you so soon as he intended.

"I shall be extreamly glad to receive Certain Accounts of a Quantity of Ironstone, the Accounts you send appear very favourable, and I hope Mr. Cadell Junr. will make Assays of them; and if Quantitys can be undoubtedly got, at a moderate price, and y^e^ carriage to Stanhouse Mill not exceeding 2/6 a ton, it will be a fine Circumstance.

"Your Account of the Wood is likewise very agreeable, when the Doctor comes to You I don't doubt You will fix upon some agreeable Plan—it seems to me that Seaton Mill may suit Us better than any other Spot, if We can get a Tack for a Term of Years, I hope soon to receive an Explicit Answer from You on that Head.

"It seems to me that the great Works will be on the Carron and that We must plant Woods in the Neighborhood, Land is Cheap enough and 20 years will bring Woods to perfection."

In September he was back at Birmingham, all the better of a first month's camping and a change of occupation. On 15th September he writes:

"I take the first opportunity after my return to this place to ask You how You do, thank God I am very well, better than I have been for many Years. I came here on Monday last and have a Leave of absence for 5 Weeks so that I shall be Month at home, unless the French should land which I do not think probable tho' the Newcastle and Hardwicke Party pretend to be much alarmed about it, they will meet with a Gallant Reception if they should, for I doubt not that many Regiments of the Militia will be found amongst the very best of the Regulars. We have been Reviewed by two Brigadiers and one Lt. General at 3 several times and had the highest Commendation, and We deserved it; many Officers of the Guards and other Corps have likewise at different times expressed their extreme surprise at the steadiness with which We perform our Evolutions, and the Alertness of our Exercise, and I believe the

Norfolk, Wiltshire and many other Regiments are as well disciplined as We are, Many of the Officers were pleased to say our Battalion might be as safely depended upon for an` Onset as any of the Standing Army in his Majesty's Service and if they had not said so We should have had no doubt of it, for We have been very Industrious. . . ."

It was, however, a long time before the fear of invasion was over. Mr. Garbett was still on duty in April, 1760, and finding, after the novelty had worn off, that soldiering was becoming a great drawback to his business. Whenever he was on leave his active mind was constantly directed to the furtherance of the great scheme.

Another of the difficulties that had to be faced was the wretched means of communication. In one of the letters written in July he tells Mr. Cadell: "You must never reckon upon anything being delivered at Prestonpans from Birmingham under 10 or 12 weeks from the time of ordering. 9 days is lost by the Post, a few days and perhaps weeks is lost in procuring the Goods at Birmingham, a week lost in sending them to London and frequently a month elapses without a ship sailing for the Firth."

Scotland was so poverty-stricken that neither materials nor mechanics were to be found near the Forth. Everything of importance had at first to be brought by sea from England. Dr. Roebuck, writing in September from Birmingham, says: "I expected by this time to have been planning with you an Iron Work in Scotland. But Mr. Garbett's attendance upon the Militia and my ill Health these five weeks past have prevented me from undertaking the journey. Though if neither of these impediments had occurred we could not with any propriety have begun the erection of the Furnace this Autumn. For the Hearth stones would not have arrived in time nor are the Bellows Boards and Axle Tree yet procured though work men have been employed nearly two months to look out and purchase them. A Furnace which is capable of being work'd with Pit Coal must be twice the size of the Furnaces which you saw and it is

difficult to procure Timber of a sufficient strength and goodness. I am promised to have the Bellows Boards forward in a week to Bristol and the stones are now I hope going down the Severn. . . . We have hired a founder who was one of the principal (sic) workmen at Colebrook Dale. The wages are high, but if the work was well established they are trifling in such a concern. If we had not hired the founder at present we could not hereafter have had an opportunity. However we must immediately endeavour to find some employment for him which must be by erecting an Air Furnace instantly in the place where we purpose to build the Bellows Furnace. . . ."

This letter shows that no progress had been made with the construction of the works on account of these difficulties by the month of September, 1759, and further that two kinds of furnaces were in use at that time, viz., *air furnaces*, worked on the ancient bloomery principle by natural draught, and *bellows*, or what are now known as *blast furnaces*. The former were small and easily built, and were constructed for charcoal fuel. The latter were much larger structures, and were intended for smelting with pit coal, which had been but rceently introduced into some ironworks in England. These little air furnaces continued to be used for many years alongside of the blast furnaces. In the Old Statistical Account we read that there were five blast furnaces and fifteen air furnaces in operation at Carron in 1797 (Vol. xix. p. 94).

The axle tree referred to was to have been 27 feet long and 30 inches in diameter, and the difficulty of finding a large enough stem shows that good trees were then very scarce in England, and did not grow in the accessible parts of Scotland at all. They had in the end to be satisfied with an axle of smaller dimensions, which was shipped from Bristol in October. Firebricks and clay from Stourbridge were also brought by Bristol, and many troubles befel the owners before the goods arrived. Mr. Garbett on 31st January, 1760, writes: "I hope the stones will be ready to go by the

Providence. . . . I shall send 10 tons of Stourbridge clay and I hope 20,000 Stourbridge Bricks. . . . We have been sadly imposed upon by our correspondent Lavender at Bristoll and Captain Hay who I find is a drunken Fellow as well as a mean Scoundrell. He actually hid himself 3 days in order to gain 3 days more Demurrage. I shall be glad to hear that the Ship is safe with you, and if you can take any advantage of Mr. Hay, pray do, for he hath been picking our Pockets in company with Mr. Lavender."

Another difficulty was that of finding skilled men to erect and work the furnaces. While the Scots were naturally prejudiced against the English, it was necessary to act with much circumspection in importing a large number of what were considered such "undesirable aliens." On the other hand, it was no easy matter to induce the latter to leave home and go boldly forth to such an unknown and uncivilised northern land, where, from all accounts, their welcome by the common people was not likely to be particularly warm. Mr. Cadell at first wanted to employ only his own countrymen, but Mr. Garbett would not hear of this, as skilled masons and furnacemen of the kind he wanted were only to be found in England.

After deciding on Englishmen, Mr Garbett says, in deference to his friend's wishes: "I hope that when these men have built us one furnace that we shall be able to build another without them as we will employ some Scotsmen as masons, bricklayers and wrights." "Eminent" men were brought from the South at the high salary of £50 a year, and were to be persuaded to come with only two men each instead of five or six, which seems to have been the usual size of the squad working under each foreman builder at that time. ". . . If they will be content with sending only two men each you see we shall be able to employ at least six Scotsmen, and if clever fellows are picked in your country I hope another time we can do without help from England, but at present it will behove us not to make the Englishmen jealous or suspicious that we intend to do without them

as soon as we can, for then there will be a cry against us and we shall not be able to get furnacemen or forgemen."

It was further advantageous to follow this prudent course, as it would "be of great use to us to have those men bring a good report of the country which the workmen have at present a strange notion of." After the first furnace was in operation and castings were being made still greater inducements were offered for skilled mechanics. By the 1st of June, 1760, Robert Hawkins, "a very knowing and experienced man," was engaged at a salary of £100 a year to teach Scotsmen the art of boring cylinders and grinding sad irons. Such pay would be equivalent to £5 or £6 a week nowadays.

The first partners were Dr. John Roebuck and his brothers Benjamin, Thomas, and Ebenezer, Mr. Samuel Garbett, Mr. William Cadell, sen., and his eldest son William, who, although only twenty-three years of age, showed such business capacity, energy and integrity of character that he was appointed resident managing partner, and remained at the head of affairs for the first nine years of the company's existence.[1]

By the end of 1759 the preliminary arrangements were completed. The original copartnership was to subsist for sixty-four years, beginning on the 11th November, 1759, although the Articles of Copartnery between the seven partners were not signed till 19th January and 9th February, 1760. Preliminary leases and agreements had been entered into by Dr. Roebuck and Mr. Garbett before that date. The Articles of Copartnery, an elaborate document of 6000 words, include an agreement to take over the leases of mills at Craigforth on the Forth above Stirling, on the Avon, Carron and Crammond (or Almond) rivers, and also to lease or buy the woods of Callander, Leny, Cowbank, Newred, Northwood and Tinnochside. A contract to feu 14 acres from Sir Michael Bruce of Stenhouse, dated

[1] It would have been of interest had the letters from, as well as to, Mr. Cadell been preserved, but only the latter have been handed down to me, as the art of copying outgoing correspondence was then in its infancy.

13th December, 1759, for a site for the principal works was also included,[1] as well as a contract for ironstone on the lands of the Earl of Errol, and for coal on the estate of Thomas Dundas of Quarrole (Carron Hall). The share capital was divided into twenty-four parts and allocated among the partners as follows:

Dr. John Roebuck	6	twenty-fourths	£3000
Samuel Garbett	6	„	3000
William Cadell, sen.	3	„	1500
William Cadell, jun.	3	„	1500
Benjamin Roebuck	2	„	1000
Thomas Roebuck	2	„	1000
Ebenezer Roebuck	2	„	1000
	24		£12,000

Each partner was liable for the amount of his share until fully paid up, and was not to be entitled to carry on ironmaking independently of the firm, or lease a colliery and sell ironstone to outsiders at a lower price than to the copartnery.

It is stated in some histories that the first blast furnace was "blown in" on the 1st of January, 1760, but this tradition is not supported by the documentary evidence in my possession. The materials for the bellows or blast furnace had not arrived by October, 1759, and it is highly improbable that it could have been completed and ready for work in two months' time. Indeed, in a letter dated 12th February, 1760, Dr. Roebuck writes to the Messrs. Cadell: "It will perhaps be most advantageous to erect the first Furnace on the Avon or near Stirling," which would seem to show that the site of

[1] A good story is told in Nimmo's *History of Stirlingshire* (3rd edition) about the acquisition of the original 14 acres for the works. Mr. Garbett, after arranging with Sir Michael Bruce, the superior, for the feu, found he had further to reckon with the agricultural tenant, whose lease had still a couple of years to run. He demanded what he thought a very moderate price as compensation for disturbance, but the Englishman considered it an exorbitant sum that could not be entertained. The latter went off to give the tenant time to reconsider his terms. In the meantime a friend called on the farmer, and suggested that the Englishman had probably mistaken pounds *Scots* for pounds *Sterling*. And so he had, but before the tenant had time to write modifying his terms, back came a letter with the company's acceptance, agreeing to pay him exactly twelve times what he asked, one pound Scots being of course worth only 20 pence, or a twelfth of a pound sterling.

the principal works had not even been definitely fixed by the beginning of that year, although a feu of 14 acres had been secured on the Carron Water. On 22nd March, 1760, Mr. Garbett writes: "I have said to Dr. Roebuck that I think the chief point is to get the Blast Furnaces at work as soon as possible. . . . Messrs. Thos. Roebuck & Co. in London think they can readily sell any quantity of Cannon Ball we can make, and wish to know how many can be cast weekly at one Air Furnace, and whether you have workmen enough to employ Furnaces at work, and whether you can get any quantity of Pigs from Glasgow."

This letter explains the position of affairs in the spring of 1760. There were, as we have seen, two kinds of furnaces at first—so-called air furnaces and blast or bellows furnaces. The former seem to have been worked by natural draught on the bloomery principle, and to have been small structures, easily erected and of far less capacity than the regular blast furnaces. Apparently they were akin to what are now known as cupolas used for foundry purposes, into which pig-iron could if necessary be charged and cast directly into cannon balls.

From this letter it appears that one or two of these had been completed by the beginning of 1760. It is thus probably only an "air furnace," and not a large blast furnace that was "blown in" on the opening day of 1760, or rather only tapped by Dr. Roebuck in the presence of the assembled guests, who greeted with deafening cheers the appearance of the molten flood. Mr. Cadell called for a bumper to the works and "long years of prosperity to Carron and Dr. Roebuck." That was a happy day, no doubt, when hearts were young and the pleasures of hope were high, but the good Doctor never lived to see the prosperity he worked so hard to win. He was a better scientist than a financier, and was obliged in a few years to sell his shares in Carron to pay his creditors, and after a life of struggle, litigation and distress he was finally overwhelmed with the disaster attending his mining operations at Bo'ness. He helped and encouraged his friend James Watt in many of his great inventions, and used Watt's first

high pressure steam engine for winding coal in the Kinneil Colliery. After he died in 1794 his remains were laid to rest in Carriden Churchyard, where a weather-worn marble slab may still be seen commemorating in flowing Greek and Latin phrases, now almost illegible, his strenuous but unfortunate career and his many admirable virtues.[1]

Neither did Mr. Garbett live to reap the reward of his labours that he had worked so hard to gain. He was ruined before 1780 chiefly through the misfortunes brought on by Charles Gascoigne, the evil genius of the company's early years, whose career will be again referred to.

[1] This neglected monument to one of Scotland's almost forgotten benefactors is now sadly weathered, and the inscription is rapidly growing dim. Before it has become entirely defaced, like all old marble monuments in this moist climate, I have had it photographed to preserve the record of the inscription, and the photograph is here reproduced. Mr. Thos. J. Salmon, Solicitor, of Bo'ness, has had the faint Latin and Greek words deciphered, but only after considerable difficulty, and translated as follows by Mr. C. A. Malcolm of the S.S.C. Library, assisted by Mr. Jas. Mill, M.A., Lecturer in Edinburgh University:

UNDERNEATH THIS TOMBSTONE RESTS
NO ORDINARY MAN
JOHN ROEBUCK, M.D.,

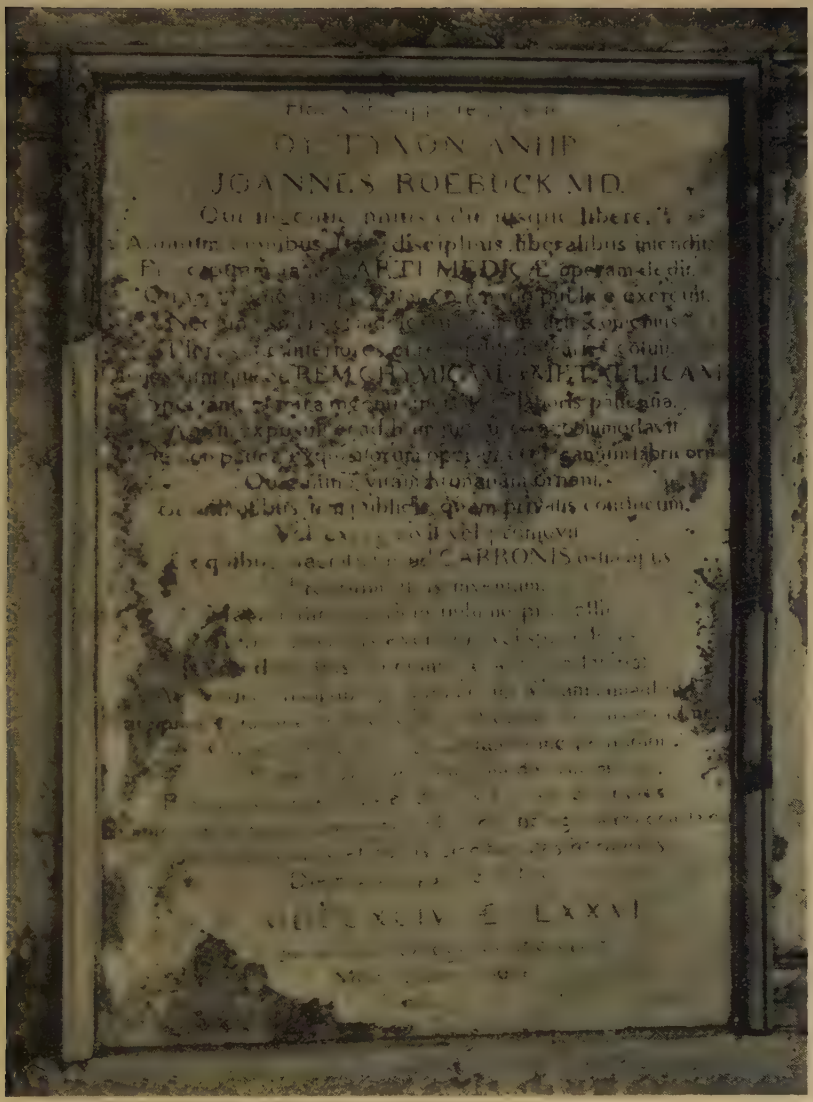
who of gentle birth and of liberal education applied his mind to almost all the liberal arts. Though he made the practice of Medicine his chief work in his public capacity to the great advantage of his fellow-citizens, yet he did not permit his inventive and tireless brain to rest satisfied with that, but cultivated a great number of recondite and abstruse sciences, among which were Chemistry and Metallurgy. These he expounded and adapted to human needs with a wonderful fertility of genius and a high degree of painstaking labour. Whence not a few of these delightful works and pleasing structures, which decorate our world and by their utility conduce to both public and private well-being, he either devised or promoted. Of these the magnificent work at the mouth of the Carron is his own invention.

In extent of friendship and of gentleness, he was surpassing great, and though harassed by adversity or deluded by hope and weighed down by so many of our griefs he yet could assuage these by his skill in the arts of the muses or in the delights of the country.

For most learned conversation and gracious familiarity no other was more welcome or more pleasant on account of his varied and profound learning, his merry games and sparkling wit and humour. And above all on account of the uprightness, benevolence and good fellowship in his character.

Bewailed by his family, and missed by all good men, he died on the Ides (*i.e.* the 15th) of July, A.D. 1794, aged 76, in the arms of his wife and with his children around him.

This monument—such as it is—the affection of friends has erected.



DR. JOHN ROEBUCK'S TOMBSTONE AT CARRIDEN.

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The original capital was £12,000, but the enterprise extended so quickly, and the prospects were so bright, that this sum soon proved quite inadequate. Three-quarters of the stock was raised in England, but the Messrs. Cadell, although co-operating with Englishmen of the most admirable character, would gladly have had more of their own countrymen for partners had any one been found willing to undertake the risk. Nobody would do so, and that is why the Carron Company, although on Scottish soil, has remained so largely an English undertaking since its incorporation. On 25th May, 1760, Mr. Cadell writes: "There is no man in Edinburgh, I believe, who has spirit enough to enter into this concern, and I suppose the only person in Glasgow would be John Glassford, whose interest might be serviceable in the American and West India mercat." John Glassford, however, did not think fit to come in, and well it was for him that this was his decision, as subsequent events will show.

Mr. Cadell, as has been said, at first wished the works to be near his home in East Lothian, but he ultimately agreed with the other partners to fix on the site at Carron. Had the projectors known that before the Company was ten years old the all-important water supply on the site chosen would sometimes fail and throw the works idle for months at a time, necessitating the introduction of steam power, while the charcoal on which so much at first depended would soon be superseded by coke from pit coal, as easily obtainable in East Lothian as in Stirlingshire, they might well have changed their minds and adopted Mr. Cadell's proposal.

Several of the letters refer to the ill-will of the people of Falkirk, a couple of miles off, and the disagreeable character of the district as a place of residence. At that time there was not a single house between Carron and Falkirk, and the ill-natured inhabitants of the old town had not yet awakened to the advantages of the new local industry, which was destined in time to become, directly and indirectly, the main source of livelihood to the whole community.

While the blast furnaces where the crude pig-iron was smelted

from the ore were thus fitted up in Carron, slitt or rolling mills and forges for making the pig into malleable iron were proposed at other convenient and not too distant places along the coast where there were meal mills which might be acquired, and where good water power was available. The only extensive ironwork of this sort which was actually established was that at Cramond, constructed shortly after the principal works at Carron were completed. The Cramond works were sold to Mr. William Cadell, jun., in 1771, and carried on independently by his family till 1860. The Cramond iron was noted for its strength and toughness, and before mild steel came into general use it was highly valued for certain kinds of work. The Cramond works before the end of the eighteenth century were highly prosperous, and had plant worth some £30,000, but as times and men changed they became unprofitable, and had at last to be sold. Like the old corn mills which they supplanted, they have been lying in ruins for more than half a century.

Nailmaking was also introduced at that time into Scotland by Mr. Cadell, and skilled nailers were brought from England to teach the ignorant Scots the useful art in different parts of the country. By 1770 Carron Company had nailmakers working at Carron, Camelon, St. Ninians, Kilsyth and Kirkcaldy, as well as at Cramond, and this continued for generations as a source of profitable home employment to a large number of poor families. In 1769 200 tons of rod iron were sold at £20 per ton to the various nailers, and the estimated profit from this branch of the company's business was £800 a year.

Up till the autumn of 1766 the Company had only two blast furnaces worked by bellows, and the small air furnaces already referred to. The whole production of iron at that date was from 35 to 40 tons a week, and this was practically all that was made in Scotland. But even with this small output the works had apparently been moderately successful, and had made a total profit from 1st January, 1762, to 1st March, 1765, of £10,213. The nations were

at war, and the trade had already begun in guns and warlike munitions that afterwards grew to enormous dimensions and made Carron famous. The original capital soon proved much too small for the extensive engagements the Company had undertaken.

The original capital in			1760 was	£12,000
It was increased in			1762 to	30,000
„	„	„	1763 „	70,000
„	„	„	1768 „	80,000
„	„	„	1771 „	150,000

The Messrs. Cadell's share at the latter date was £20,273, and the Garbett family's £50,683, and the shares being not fully paid up, a heavy liability was placed on the partners, which most of them could but ill afford to meet. Mr. Wm. Cadell, jun., who had been appointed resident managing partner in 1760, at the handsome salary of £100 a year, in addition to his share of the profits, as a cautious Scot entirely disapproved of the extravagance and mismanagement of some of the departments, largely under the charge of Englishmen, who were beyond his control. He repeatedly, but without effect, protested in writing to Mr. Garbett against these abuses. In order to supervise operations adequately he had come to reside permanently in the district, which was then a most undesirable one, and in 1763 had built his house of Carronpark, on the high ground to the west, overlooking the works.[1] In spite of all his trouble and anxiety he could not get his wishes carried out, although he had personally made large outlays, and had devoted several of his best years to the Company's service.

In the end of 1766 two new blast furnaces, Nos. 3 and 4, were added. No. 3 was "blown in" on 18th October, and No. 4 a few months later, and for the blast iron cylinders instead of leather bellows were employed, the motive power being still water from the Carron.

[1] Carronpark was sold by the writer to Carron Company in 1905, and has since been demolished.

Mr. Cadell disapproved of this addition to the plant, which had cost from £12,000 to £15,000, but he made an estimate to Mr. Garbett of the profits that might be expected in 1767 if the business was economically managed.

The expected profit from four blast furnaces was	£8,000
From air furnaces	1,000
From slitt mill	1,000
From forge	1,000
From Kinnaird Colliery	1,500
	£12,500
Less interest and bank commissions	2,000
Leaving a nett divisible profit of	£10,500

sufficient to pay 10 per cent. on the Company's capital. But alas for their great expectations! Instead of a profit the end of 1767 showed a loss of £10,000.

Efficient servants to superintend the different departments, and particularly the furnaces, were difficult to find. Occasionally the loom castings and the guns were badly cast, and sometimes the latter were bored to a wrong calibre, the consequence of which was that cannon to the value of £5000 were rejected at Woolwich on one occasion. To add to the troubles, the summer of 1767 was so dry that the water supply, originally intended for only two furnaces, but now harnessed to drive four, entirely failed, and threw the works idle for three months, necessitating by-and-by more capital for the erection of a costly steam engine on the new principle lately invented by James Watt.

The water from the River Carron had been impounded in reservoirs 30 acres in extent,[1] but even this supply at times ran short. The new engine, which was employed in dry weather for many years, was used not to produce the blast directly on the modern principle, but to raise the spent water from the tail race and return it

[1] This is the water seen in the foreground of the photograph of the works in 1912.

to the large overshot water wheels that worked the bellows, hammers, and other machinery. It was powerful enough to raise four tons of water at every stroke to a height of about 25 or 30 feet, and worked at a speed of seven strokes a minute, with a consumption of 16 tons of coal every 24 hours.

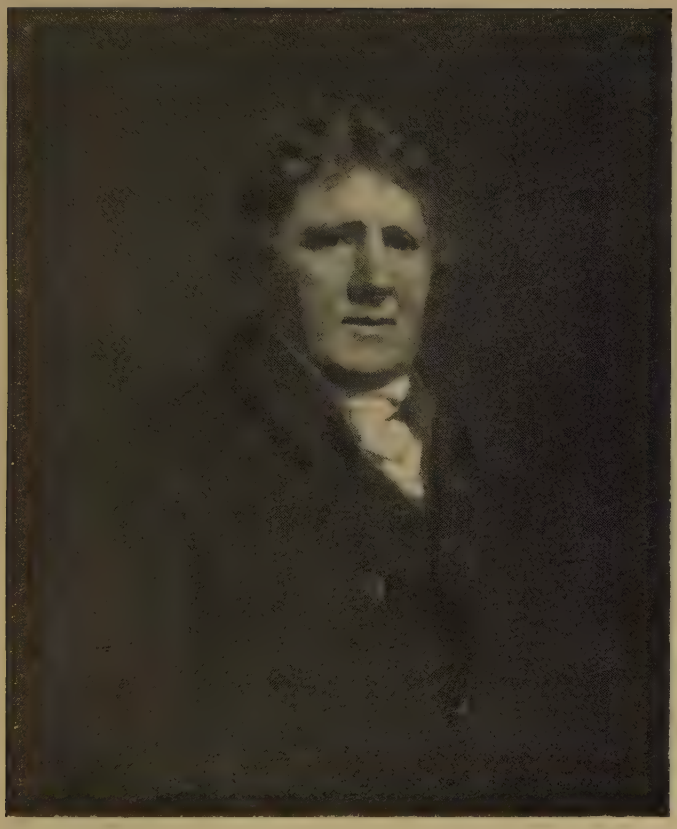
Mr. Cadell, sick at heart, writes to Mr. Garbett on 18th July, 1767: "I have now been above seven years at this place and indeed no prospect of Gain would make me again go thro' the same scene of fatigue, vexation and perturbation of mind as well as body which I have experienced almost without intermission. That disagreeable cup is in some degree over, but even with the prospect now before me I am confident I should otherways employ my Time and Money to greater advantage and much more to my own Ease and Peace of Mind by confining my concerns to such compass as I am certain can be properly and profitably executed, for these reasons whenever it is convenient and agreeable to the Company that I should otherways employ my time and Money I will be very glad to do it and hope I can employ both without prejudice to Carron."

Again, on 27th September, 1767, he writes referring to the original much more cautious and modest plan his father and he had originally conceived: "You and Doctor Roebuck determined to enter into the Trade on a much more Extensive Plan in which you gave us an option of being concerned and we accordingly agreed to engage £3000 in it. I do not throw blame upon the conduct of any Person but I must in Justice to myself say that the utmost endeavours on my part have not been wanting for the good of this Trade. It has always been my opinion that the utmost attention and *Frugality* in every circumstance was necessary to make this undertaking go on with the needful success and Profit. It has given me great vexation to see such deficiency in both these particulars and in my opinion as a Work of Profit—and not of Pomp—it is still absolutely necessary to persevere in the establishing of these Two Points, but I hope I shall not be left the Single Partner to fight for such an establishment

and perhaps be thought disrespectfully or unjustly of for the attempt. . . ."

While many difficulties and disappointments were met with during the first decade, the foundations of a huge national industry were all the time being solidly laid. The great trade in guns and warlike munitions had begun, and no doubt Mr. Garbett's connection with the War Office through his commission as colonel of militia was very useful to the company at first. There was also, it must be remembered, no other iron-smelting work in Scotland at that period except the small furnaces at Bonawe and Goatfield, and therefore Carron Company enjoyed a practical monopoly of the local trade in all kinds of cast and malleable iron goods. The old letters tell of much distress for want of capital, but that seems to have been mainly because the English partners were too enterprising and speculative, and in Mr. Cadell's opinion, too extravagant in their ideas and not nearly cautious enough in their methods. The actual profit at the works on every manufactured ton was considerable, and from a document in my possession it appears to have been as much as 20 per cent. for 1770 and 1771. Had the development been more gradual many of the financial troubles might not have arisen.

By 1771 the prospects had so far improved that several new partners came in, and it was found necessary to adopt new articles of copartnery by which the copartnership was extended to 99 years from Martinmas, 1770. The new agreement was thus to last till 1869. The capital was now fixed at £150,000, divided into 600 shares of £250 each, at which it has since remained. No partner was to have a right to vote as a managing partner in the direction of the Company's affairs unless he held ten shares or £2,500 of stock, which entitled him to one vote, and a committee of managing partners was appointed to meet monthly and supervise the business. The style of the original copartnery was "Roebucks, Garbett and Cadells," but the name "Carron Company," which had been used for some years unofficially, was now adopted as the official designation



WILLIAM CADELL OF BANTON AND GRANGE (b. 1737, d. 1819).

Portrait by Raeburn, 1810.

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instead of the original title, which was abolished. The new articles were signed by the following partners:

Samuel Garbett,	Francis Garbett,
Ralph Lodge,	Benjamin Roebuck,
John Minyer,	Thomas Roebuck,
Ebenezer Roebuck,	William Cadell, jun.,
John Adam,	John Cadell,
Charles Gascoigne,	William Cadell, sen.

Among the new partners was John Adam of Maryburgh in Kinross-shire, brother of Robert Adam, the celebrated architect, and father of the Right Hon. William Adam of Blair Adam, M.P., one of whose distinguished sons was Admiral Sir Charles Adam, the father of the Right Hon. William Patrick Adam, M.P., of Blair Adam, who died in 1881. The distinguished Blair Adam family, with their naval and military connections, thus became associated with Carron Company at an early date in its career.

John Cadell of Cockenzie, another of the new partners, was the younger son of William Cadell, sen.,[1] and was father of Robert Cadell, whose name is known to literary men as the friend and business associate of Sir Walter Scott. He was the grandfather of Col. Thomas Cadell, V.C., C.B., the present proprietor of Cockenzie House.

Another character who appears on the scene is Charles Gascoigne, whose remarkable career will be followed afterwards.

Dr. Roebuck's name had disappeared from the list of partners before 1770. He had some years previously become involved in the Bo'ness colliery, for which Carron Company had provided plant and furnishings to the value of several thousands of pounds. To pay his debt all his shares had to be sold to some of the other partners, and

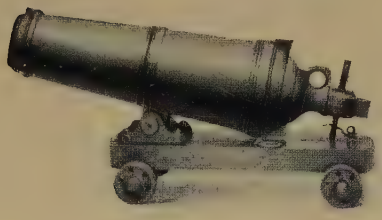
[1] William Cadell, sen., died in 1777, and the Mr. Cadell referred to in the sequel is his eldest son, William Cadell of Banton and Grange (great-grandfather of the writer), who was born in 1737 and died in 1819.

his connection with the company was never again renewed. It is sad to reflect on the misfortune that overwhelmed the good Doctor. For want of sufficient geological knowledge he just missed a huge success. The blackband ironstone that was afterwards discovered in his abandoned pits of Kinneil was not known to him to be of any value, and the fortune that should have been his was left lying to be easily won by another generation.

In 1773 the Company became so important that a Royal Charter was granted erecting it into a Body Politic with powers to sue and be sued as a legally established Corporation. The capital was fixed at £150,000 in shares of £250, and £130,000 of this was paid up. Two more shareholders had joined, and the number of partners was twelve. The Charter provided, *inter alia*, that regular and correct accounts were to be kept, and a true statement of the Company's affairs was to be made up annually and entered into a book kept for the purpose, which should be always open to the inspection and examination of all the proprietors of the Corporation.

The interests of all the shareholders were thus theoretically safeguarded. How this excellent rule was adhered to by the subsequent managing partners of the Company will, with other important matters, be related in the next chapter.

CARRON ORDNANCE.



A CARRONADE.

SIX-INCH GUN WEIGHING 36 CWTS. CAST AT CARRON IN 1792.

Brought from Bellary Fort, Southern India, and presented by the author to the town of Bo'ness at Coronation of King Edward in 1902. It is placed in the Victoria Public Park, and must be fired at least once a year.

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CHAPTER X.

CARRON COMPANY (Continued).

THE other chapters of this sober chronicle relate mainly to things inanimate, to scientific facts and theories, and practical or unpractical plans and achievements of more or less worthy men. But many people nowadays like to hear about men rather than things, and to such readers this chapter may prove more interesting than some that have preceded it.

The personal equation enters largely into the history of Carron Company, and particularly into the latter part of it. The *dramatis personae* of the old comedy—or tragedy, as it no doubt appeared to some of the actors—have long ago gone to their account and their children after them. Nobody living has therefore any reason to feel offended if some of their queer proceedings are now briefly mentioned in connection with other episodes for the benefit or warning, as the case may be, of a new generation that knows not Joseph. The Joseph, it may incidentally be explained in anticipation, many of whose doings have thus been forgotten, is not known to have been a son of Jacob at all, although he had many Hebrew proclivities, including a remarkable capacity for business and a very strong sense of family affection. This Joseph and a few of the doings of his capable and acquisitive family circle will be referred to afterwards.

Charles Gascoigne was one of these personages so dear to writers of fiction, a man of the world, with far more cleverness than uprightness

in his versatile character. He was a son of Captain Woodruffe Gascoigne, an English officer sent to "settle" the Highlands after the '45, and his mother was the Hon. Grizel Elphinstone, daughter of Charles, ninth Lord Elphinstone. This eligible young gentleman was taken as a boy into Mr. Garbett's family, and remained as a protegé until he had reached the years of discretion.

Before he came to Scotland he had been engaged in business as a drysalter or wholesale dealer in chemicals and drugs in London.[1] He was at first a great favourite, and in 1759 was permitted to marry Mr. Garbett's daughter. For several years thereafter he was reckoned a very dear son of the family, but in course of time he became less beloved by his kind papa, while at the same time he became a great deal "dearer" to all the family. "You may be assured, my dear Charles," Mr. Garbett writes on 7th Feb., 1769, "that I feel very gratefully your attention, that I congratulate myself upon having such a son, and that I am truly sensible of the great importance you are of to me and to our whole family. . . ." On 25th March he writes again: "I need not say to you, my dear Charles, how often I have lately congratulated myself upon the significant support I receive from you. I feel it very sensibly, and it is particularly fortunate for me at my time of life. I have extreme pleasure in seeing how very comfortable your house will be; and if you can manage it so as to avoid being teized by W. C. (William Cadell, the manager), and the works improve as I expect, I have good reason to hope we shall all be very happy."

This letter shows that Mr. Gascoigne's merits were not so highly appraised by the manager, and indeed so far back as 1765 the correspondence shows that the other partners had absolutely objected to allowing him to become a partner at all, and it was only with difficulty that Mr. Garbett obtained their consent to his admission.

[1] Vide *New Statistical Account of Larbert Parish*, 1842. Written by Lt.-Col. W. Dundas and William Archibald Cadell, F.R.S. (eldest son of William Cadell, the first manager), who were contemporaries of Mr. Gascoigne.

Mr. Gascoigne had been permitted in 1763 imprudently, as Mr. Garbett afterwards admitted, to form an establishment at Carron Wharf near the works, for carrying on manufactures, first under the name of Samuel Garbett and Coy., and afterwards as Francis Garbett and Coy. Mr. Gascoigne was sole manager of that establishment until 1772 when the crash came, and the firm suspended payment with liabilities of £193,054 19s. 3d., and very few assets to show on the other side of the account. The son-in-law had involved his too-trusting benefactor in debt to the extent of more than £100,000, and thereafter the affectionate family correspondence came to an abrupt termination.

While these things were in progress outside, Mr. Gascoigne was complaining bitterly to Mr. Garbett about Mr. Cadell's being allowed to act as manager of the Carron works, and urging the necessity of dispossessing him of that position. Mr. Garbett was, however, not of that way of thinking, as he refers to "the well-known attention, acuteness, and honesty of Mr. Cadell, the manager, and Mr. Grieve, the bookkeeper," and mentions the fact that "a clear and distinct state of Carron Company's debts and effects drawn out from their books by Mr. Grieve, together with Mr. Cadell's very accurate half-yearly remarks, were circulated regularly among all the partners, and were highly and justly applauded."

Before the catastrophe to the Carron wharf business, however, Mr. Cadell had, as the correspondence in last chapter indicates, grown sick of the management and resigned voluntarily in 1769. Mr. Gascoigne thereupon, while his credit still appeared good, got himself appointed to the vacant post, and held it for several years. A great dispute broke out between himself, the Carron Company, and Mr. Garbett before 1779, into the merits of which we need not enter. Pamphlets were circulated which Mr. Garbett described as atrocious calumnies, and to which he was moved to reply in the English law courts in 1779, from whose voluminous records these particulars have been obtained. The Garbett family ended in being ruined,

and Mr. Samuel Garbett was chased more than once out of Scotland by his creditors.

Matters at last became too hot for "dear" Charles also. The offer of a lucrative situation had been made him through the medium of another Scot abroad, Admiral Greig, a native of Inverkeithing, and at that time a distinguished officer in the Russian Navy. He accepted it with alacrity and fled the country, taking with him, it is said, as much of the Company's money as he could conveniently lay hands on. He absconded to Russia, whose Government had been a large purchaser of Carron guns, and contrary to law he also took with him several workmen skilled in the art of making good ordnance. His cleverness never forsook him, and to it was added experience in managing men, and women too, it would appear. He obtained an appointment from the Czarina Catherine II. at a salary of 30,000 roubles or £4500[1] a year, for whom he erected a grand cannon foundry at Petrozavodsky, near Lake Onega, in the Government of Olonetz. He also erected another ironwork near the Black Sea, and for his valuable services was created a Knight of the Order of St. Vladimir and given the rank of General in the Russian Army and Councillor to the Empress of Russia. His first wife died, and he married again in 1797. His second wife was a daughter of Matthew Guthrie, M.D., Physician to the Czar Paul. He had a family of three daughters, but no son to succeed him. Many years after his change of nationality he returned to Scotland, incognito, but was recognised by his creditors, who chased him to the east coast near Tyningham Castle, where he only escaped their vengeance by seizing a fishing smack and fleeing across the sea to Sweden.[2] He died at St. Petersburg in 1806, leaving a fortune of £30,000, but only a small part of this was realised by his heirs or creditors in Scotland.

Two of the disloyal Scots workmen who went with him likewise attained distinction, like many more of their countrymen at that

[1] Tooke's *Russia*, 1799, vol. iii. p. 550.

[2] See *Some Professional Recollections*.

time, in the half-civilised Muscovite Empire.[1] Charles Baird established works at Cronstadt for the manufacture of guns, steam-engines, and other iron goods. He too was created a Knight of St. Vladimir. He died at Cronstadt in 1843 at the age of seventy-two. His companion, Wilson by name, succeeded Gascoigne in the management of the works at Petrozavodsky. He also lived to a good old age, and was given the rank of General in consideration of his long and useful services to the Russian Empire.

Mr. Cadell, although still a shareholder and interested in the success of the company, was on retiring from the management relieved of an uncomfortable position and was free to attend to other industrial developments in the district. In 1767 he had bought the estate of Banton, in Kilsyth parish, where he discovered a good seam of ironstone. This was let to the Carron Company at a royalty of £4 per 100 tons. Carron Company was thus provided with ironstone and at the same time saved from raising more capital at a time when capital was very difficult to obtain. But, instead of being thankful, the other partners took offence at Mr. Cadell for this very sensible proceeding. The Messrs. Cadell in 1770 also took a lease of the Grange coalfield, situated alongside of Dr. Roebuck's colliery at Bo'ness, and also a lease of the Pitfirrane coalfield in Fife. They were thus able to supply Carron furnaces with coal and ironstone from additional sources. In 1788 Mr. John Belchier, the owner of Grange, became bankrupt, when the mineral tenants bought the estate outright and proceeded to sink new pits along the shore at Grangepans and to develop the coalfield still more energetically. These old shafts, after having been closed for many years, were recently reopened by the writer and are now regularly producing coal from underneath the Firth of Forth.

In 1771 Mr. William Cadell sold his share in Carron in exchange for the malleable ironworks at Cramond as we have seen, and was thus at liberty to carry out his extensive schemes without

[1] *New Statistical Account*, Stirlingshire (1842), pp. 355-6.

interference. These and other industrial concerns were attended with more or less success, and gave fresh employment to a large number of people in different places.

Shortly after the Royal Charter was granted in 1773 the Messrs. Cadell sold out all their remaining Carron shares and thus ceased to be immediately connected with the further career of the Company. They did not believe in putting all their eggs in one basket, and thus escaped the storms which nearly wrecked the business after Mr. Cadell's steadying hand was loosed from the helm and Mr. Gascoigne had become the pilot.

The great difficulty at that time seems to have been the want of working capital and not the want of profitable work. All the large money transactions were done by means of bills, numbers of which for great sums were constantly in circulation. So much money was always on loan that it was often doubtful whether the partners were solvent or not, and it is somewhat difficult to understand how such an immense and apparently profitable business should have been in constant financial difficulties. An old man at Grange once told me he had heard it traditionally reported that sometimes the Carron manager was so hard up for money to pay the men that he had to send to Grange and borrow as much as would make up the weekly pay-bill.

However that may be, the pay-bill must have been considerable by the year 1777. Nimmo, in the first edition of his *History of Stirlingshire*, says that nearly 2000 men were at that time employed at Carron. "Two great furnaces frightful to behold, are kept perpetually burning to melt the ore," reminding the classical reader of Virgil's description of the furnace of Vulcan.

After describing the various domestic utensils and implements of peace and war which were being turned out, he sagely observes (p. 464): "It occasions an unpleasant reflection to a benevolent mind, that one part of the human race should find their advantage in forging instruments to destroy another; and that the demand for

the horrid engines of death, should often exceed that for the utensils of agriculture and domestic convenience. . . ."

"The furnaces are day and night fed with coal and wood, both which are reduced into charcoal before they are thrown into them. They are blown with bellows of a monstrous size, and of a cylindrical construction, whose force is said to be much greater than that of those of the common form. As these bellows are too unwieldy for the hands of men, they expand and contract by the motion of wheels driven by water, and the sound of their blast is most hideous. In order to obtain a sufficient supply of water for driving these wheels, which are never allowed to stand still, the whole process depending upon their motion, much labour and expence have been laid out, in forming ponds or dams in the river, and reservoirs upon its banks, besides the erection of a fire-engine, which, in very dry seasons, when other sources diminish, draws the water back again, and throws it into the pond, to supply the engines anew. . . .

"At first the workmen employed in this manufacture were mostly brought from England; but, at present, it is chiefly carried on by natives of Scotland, who are found to be fully as expert in the different operations as the English, and, as they can be content with more homely fare, do not require so high wages.

"The erection of this work hath quite altered the face of the country around it. Besides the numerous buildings raised for carrying on the manufacture, in a spot where formerly there was not a single house, several villages have been erected for the convenience of the workmen. The neighbouring fields have been enclosed and improven, many spots, which were formerly quite barren, have been cultivated, and turned to good account; and sundry proprietors have let lands, either to the company, or to individual members of it, in feus or leases, at very high rents."

In 1784 the works had developed still further when Scotland was visited by the eminent French traveller, Faujas de St. Fond. As a man of science and accurate observation he was deeply

interested in all scientific processes, and the following account of his visit is thus particularly reliable and instructive. He found it was necessary to be properly introduced before admission could be obtained. Another eminent visitor a few years afterwards, mainly for want of this useful precaution, met with a very different reception. St. Fond was introduced by a German, Dr. Swediaur, who was living at Prestonpans and had previously shown him Dr. Roebuck's vitriol works in that locality. Swediaur was also a practical scientist endeavouring to make salt on a new principle from sea water, and no doubt while living at Prestonpans he had met Mr. Cadell and so made the acquaintance of the Carron officials.[1]

St. Fond's Visit to Carron Works, 1784.

"He had the goodness to accompany me back, with the intention of taking me the next day to Carron, to visit the greatest iron-foundry in Europe, but where it is impossible to obtain admission without very strong recommendations. Swediaur was acquainted there; and I thought myself exceedingly lucky to be able to make this useful excursion under his auspices. . . .

"Immediately on our arrival, Swediaur wrote a note to a person belonging to the manufactory, with whom he was acquainted. An answer was returned, that it was necessary to leave the name, designation, and residence of each of us. The demand was instantly complied with; and a few minutes after we were told that we were at liberty to enter.

"A man attended us at the gate, who said that he was ordered to conduct us everywhere, with the exception of the place where the cannons are bored, which nobody was allowed to see.

"He conducted us at first into an immense yard, surrounded with high walls and vast sheds. This place was covered with cannons,

[1] Faujas de St. Fond, *Travels in England and Scotland*, 1784. Edited by Sir Arch. Geikie, 1907. Vol. i. pp. 177-186.

mortars, bombs, balls, and those large pieces, short and expanded at the breech, which bear the name of *carronades*. Amidst these machines of war, these terrible instruments of death, gigantic cranes, capstans of every kind, levers, and assemblages of pullies, serving to move so many heavy loads, are erected in situations convenient for that purpose. Their various movements, the shrill creaking of pullies, the continued noise of hammers, the activity of those arms which give the impulse to so many machines;—everything here presents a spectacle as new as it is interesting,

"Under the sheds where the finished articles are deposited, we saw several rows of rampart cannon, siege-guns, and field-pieces, destined for Russia and the Emperor. They were longer than usual, of the most perfect workmanship, and covered with a thin varnish, of a steel colour, to preserve them from rust. Their carriages of cast-iron are remarkably simple; they appeared to me to unite the merit of the greatest solidity, to that of being free from the numerous appendages belonging to wooden carriages, which serve only to embarrass manœuvres, to obstruct the march, and to require frequent repairs.

"The coating with which the cannons are covered is kept a great secret; but I am inclined to think, that it is composed of a fat, quickly-drying oil, to which is added a certain portion of amber-varnish mixed with some plumbago.

"The large work shops where the cannons are bored are not far from the first yard. We passed close by them; but were very politely told, that particular processes and machines unknown to every other establishment of the kind, rendered it necessary to keep that place concealed from strangers. We thought this was very reasonable, and followed our conductor to another quarter.

"We were conducted to the works for melting the ore; where four furnaces, of forty-five feet in height, devoured both night and day enormous masses of coals and metal. One may from this judge of the quantity of air necessary to feed these burning gulfs, which

disgorged, every six hours, streams of liquid iron. Each furnace is supplied by four air-pumps, of the largest size; where the air, compressed into iron cylinders, uniting into one pipe, and directed towards the flame, produces a sharp whistling noise, and so violent a tremor, that one not previously informed of it, could hardly avoid a feeling of terror. These air-machines, or species of gigantic bellows, are put in motion by the action of water. Such a torrent of air is indispensably necessary to maintain, in the highest state of ignition, a column of coal and ore 45 feet high; and it is so rapid and active, that it projects a vivid and brisk flame more than 10 feet above the top of the furnace.

"An open area, of very great extent, built in the form of a terrace, and on a level with the upper aperture of the fire-places, is appropriated to the reception of the supplies of ore and coals; and on this platform are also spacious places, where the coal is prepared for use. As the coal employed here consists almost wholly of large lumps, the process by which they convert it into *coke* is completely different from that employed at Newcastle, where only coal-dust is used. At Carron foundry, this operation takes place in the open air, and is of the greatest simplicity. A quantity of coal is placed on the ground, in a round heap, of from 12 to 15 feet in diameter, and about two feet in height. As many as possible of the large pieces are set on end, to form passages for the air; above them are thrown the smaller pieces and coal-dust, and in the midst of this circular heap a vacancy is left about a foot wide, where a few faggots are placed to kindle it. Four or five apertures of this kind are formed round the ring, particularly on the side exposed to the wind. There is seldom, indeed, occasion to light it with wood; for these works being always in action, they generally use a few shovels of coal already burning, which acts more rapidly than wood, and soon kindles the surrounding pile.

"As the fire spreads, the mass increases in bulk, swells up, becomes spongy and light, cakes into one body, and at length loses its bitumen, and emits no more smoke. It then acquires a red, uniform

colour, inclining a little to white; in which state it begins to crack and split open, and to get distorted into the shape of a mushroom.

"At this moment, the heap must be quickly covered with ashes, of which there is always a sufficient provision around the numerous fires where the coal is prepared in this manner.

"The spreading of a tolerably large quantity of ashes over the fire to deprive it of air, is similar to the process used in making wood-charcoal, which is covered over with earth. The result is also nearly the same; for the coal, thus prepared, is light and sonorous, and produces the same effect in high furnaces as wood-charcoal. This is a quality of extreme importance; since, by the use of coal, foundries may easily be established in places where the want of wood would otherwise render it necessary to abandon the richest mines of iron.

"There is here such a great series of these places for making coke, to supply so vast a consumption, that the air is heated for some distance, and at night everything is resplendent from the fires and the light. When one observed, some way off, so many masses of burning coal on one side, and on the other side so many sheaves of flame, darting to a great height above the high furnaces—and at the same time hears the noise of the heavy hammers as they strike on resounding anvils, mingled with the sharp whistling of the blast-pumps—one doubts whether he is not at the foot of a volcano in eruption, or whether he has been transported by some magic spell to the brink of the cavern, where Vulcan and his Cyclops are busy forging thunderbolts.

"I wished that Volaire, the painter of Vesuvius, who has so well expressed the terrific aspect of that volcano during its most violent nocturnal eruptions, would come here to exercise his brush on this artificial volcano, which he would find no less striking than the other.

"The supplies of ore are on the same terrace with the coals. A canal, dug at a great expense, and which communicates with the sea, serves to convey all the materials used, and to transport its manufactured productions.

"Three kinds of ore are employed here, which are stored up in distinct and separate heaps.

"The first consists of a decomposed hematite, which is procured from the county of Cumberland. It is reddish, soft to the touch, and stains the hand nearly of a blood colour: it is very rich in iron.

"The second is a hard rocky iron-ore, of a yellowish brown colour.

"The third, of a deep iron-grey colour, sometimes inclining a little to violet, is remarkable for being formed in geodes (septarian nodules), of a round or oval form, a little flattened. The largest of these geodes are about 18 inches in diameter, and the least from 4 to 5 inches." .....

The flare of the Carron furnaces seemed terrific at times to residenters as well as to strangers. The accompanying illustration from *Kay's Original Portraits* is reproduced to show what some artistic people thought of the nocturnal blazes in 1797. The drawing illustrates an amusing incident in the career of a local celebrity. "Copperbottoms" was the nickname of a well known and not too popular laird in the vicinity. This individual by clever cornering of the market for copper plates used for protecting the bottoms of vessels in the Navy had quickly risen from a humble position to one of affluence. With the large fortune thus acquired he had purchased an extensive estate near Falkirk by outbidding the descendants of the ancient and much respected local family, whose lands had been attainted in 1715 and bought by the York Buildings Company, and who were in the way to recover their former territory when the public sale by the company took place. One night, the story goes, at a time when there were disturbances in the district, "Copperbottoms" was so alarmed by a hostile demonstration at his gate that he fled from his mansion-house in terror, and after retreating to a respectful distance looked round and saw through the trees that the sky was all ablaze. Taking this for the destruction of his residence, he fled precipitately to Edinburgh and obtained a troop

John Kay, 1797

"COPPERBOTTOM'S RETREAT, OR A VIEW OF CARRON WORK!!!"

To face page 182.

of cavalry for his protection. But when he returned the house was still standing unhurt, while the Carron blazes were as bright as ever.

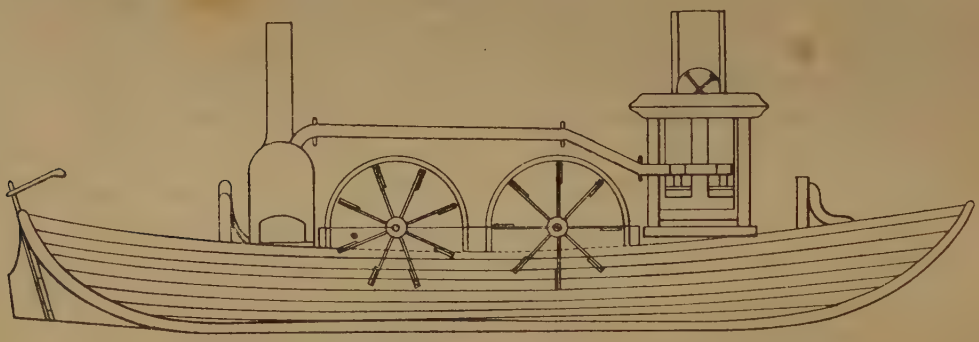
Carron Company had become the largest and most famous producer of iron and all kinds of iron goods in Europe before the end of the eighteenth century. The nations were still at war, and Britain thus needed good guns and all kinds of serviceable shot and shell for her Navy and Army. The most famous pieces of ordnance made at Carron were called "smashers" or *Carronades*, a new word to the English vocabulary, applied to the small naval cannons as distinguished from the heavier guns that were also turned out in large quantities. It is said that Carron guns were so well made that they were never known to burst, and carronades were used in every man-o'-war. The demand for such excellent weapons was not confined to the British Government. Large numbers were sold to Spain, and Russia, and other countries, and the East India Company were extensive purchasers up till 1822. The business with the British Ordnance Department lasted till 1848, when newer patterns of guns were introduced, and these were made elsewhere.

But gunmaking was not the only thing that entitled Carron works to a foremost place in Scottish industrial history. Carron was associated with James Watt in the carrying out of his earlier inventions. His first steam engine for winding coal was made at Carron works, and erected at the Burn Pit, one of Dr. Roebuck's shafts near Bo'ness, in 1768, and continued in operation till about 1825.

Steam navigation also had its cradle at Carron. Patrick Miller of Dalswinton had in 1788 constructed a small pleasure steamer with 4-inch cylinders, but she was only a model to show how the thing could be done, and not a cargo boat. The first real steamship built in the United Kingdom was constructed by William Symington, and launched on the River Carron in 1789. She was, it is believed, unnamed. The accompanying drawing, taken from an old plan, shows her general outline. Her engines, which had been patented in

1786, were made in the Carron works at a cost of £363 10s. 10d.,[1] without any help from outside, at the expense of Patrick Miller, Esq., of Dalswinton. A second experimental steamer, the "Charlotte Dundas," was constructed by Symington in 1801 at the expense of Thomas, Lord Dundas, to run on the Forth and Clyde Canal. She made her trial trip in 1802, which was attended with complete success, and opened up the long vista of modern steam navigation.

This brings us to another branch of Carron Company's enterprise. There were no railways at first, and small sailing ships or sloops were the bearers of nearly all merchandise to and from the



THE FIRST BRITISH STEAMSHIP, MADE AT CARRON, 1789.

works. In 1779 the "Carron Shipping Company" had begun to carry not only goods but also passengers between Carron and London. The Carron Shipping Company was a separate business in the vicinity belonging to Captain Elphinstone, and not at that time a part of the Carron Company's undertaking. Travelling by sea had many perils in those troublous times. The quaint advertisement on next page shows the advantage of the strong man armed and the benefit to travellers of some military training.

That modest beginning, when Carron Company took up the business afterwards, developed into a service of first-class steamers,

[1] Vide *A Century and a Half of Commercial Enterprise*, the title of a booklet published by Carron Company in 1909.

carrying goods and passengers between Grangemouth, Bo'ness and London four times weekly each way.[1]

The works were visited by potentates and crowned heads at different times, and in 1787 by no less a celebrity than Robert Burns

At CARRON—For LONDON,

To ſail March 5, 1779.

THE GLASGOW, Robert Paterſon maſter, mounting fourteen twelve pounders, and men anſwerable. For freight or paſſage, apply to Mr. G. Hamilton, Glaſgow, Meſſ. James Anderſon & Co. Leith, or the Carron Shipping Company at Carron Wharf.

N. B. The Carron veſſels are fitted out in the moſt complete manner for defence, at a very conſiderable expence, and are well provided with ſmall arms. All mariners, recruiting parties, ſoldiers upon furlow, and all other ſteerage paſſengers who have been accuſtomed to the uſe of fire arms, and who will engage to aſſiſt in defending themſelves, will be accommodated with their paſſage to or from London, upon ſatisfying the maſters for their proviſions, which in no inſtance ſhall exceed 10s. 6d. ſterling.

The Carron veſſels ſail regularly as uſual, without waiting for the convoy.

the national bard. Had he seen all he wished, the poetic literature of Scotland might have been enriched by something better than the following coarse lines, which he scratched on the window of the adjoining inn after his call. It must be explained that he made three bad mistakes, all of which St. Fond had avoided. 1. He came on a Sunday; 2. He came without the necessary introduction; and 3. He was not honest enough to give his proper name. The consequence was that he was refused admission, and vented his feelings as follows:

"We cam na here to view your warks,
In hopes to be mair wise,
But only, lest we gang tae hell,
It may be nae surprise;
But when we tirl'd at your door,
Your porter dought na hear us;
Sae may, should we to hell's yett come,
Your billy Satan sair us."

[1] See footnote on previous page.

To these lines Mr. Symington's father-in-law, Mr. Benson, who was employed at the works, penned the following appropriate reply:

"If you came here to see our works,
You should have been more civil
Than to give a fictitious name,
In hopes to cheat the Devil.
Six days a week to you and all,
We think it very well:
The other, if you go to church,
May keep you out of hell."

It so happens that in that very year, 1787, Burns published the Edinburgh edition of his poems, and Mr. William Cadell was one of the subscribers. Had the poet shown a little more sense and good feeling he might have called on Mr. Cadell at his residence of Carron-park only a mile off, and gone to the kirk with him instead of spending the afternoon in a public-house, when, no doubt, Mr. Cadell would have been glad to take him through the works in the evening, and so save the diabolic correspondence between the rival poets.

After Mr. Gascoigne disappeared from the scene the Company's affairs were left in a bad way, notwithstanding the great extent of the business. The partners looked about for a capable manager, and at last found the man who was to save the situation in the person of Joseph Stainton. The Joseph who became prime minister of Carron in 1786 reigned supreme in its councils for thirty-nine happy years, and his family after him. He had originally been a watchmaker at Keswick, and had a few years previously gone to Carron in a very subordinate capacity. He used his great business talents to the best advantage, and in a short time acquired a thorough knowledge of what was wanted to put matters to rights.

He was a man of remarkable ability and tenacity of purpose, and soon succeeded in making Carron one of the most prosperous commercial enterprises of the time. A regular dividend of 5 per cent. was paid yearly from 1788 till 1805, and of 9 per cent. from that date

till 1839. Like his great namesake of antiquity, he had numerous relations—clever men, too—for whom he had a strong family affection. He further befriended them by bringing them all in to partake of his prosperity in some way or other, and Carron became to them all a veritable land of Goshen. Curiously enough, there is a hamlet of this very name just outside the Company's gates, but whether or not it was he who named it so I do not know.

In 1808 he appointed his brother Henry agent in London. Henry was as clever as he was himself, and indeed cleverer in some respects, as was discovered after his posthumous papers were investigated. He occupied the London agency for forty-three years until his death in 1851. A cousin, Thomas Crosthwaite, was appointed in 1801 manager of the branch which had been opened in Liverpool, and on Crosthwaite's death in 1830, Henry Dawson, another nephew, took his place. A third nephew, Thomas Dawson, became the manager of the Glasgow office, and a fourth nephew, Joseph Dawson, became sub-manager at Carron and chief manager after Joseph Stainton's death in 1825. On his death in 1850 he was succeeded by yet another nephew, William Dawson. There was thus introduced at the beginning of the nineteenth century a powerful clan of Staintons and Dawsons, among whom all the important appointments were distributed, and Carron became a strict family preserve for a couple of generations.

There was no harm in having the business thus turned more or less into a family affair provided those shareholders who had the misfortune to be outside the charmed circle were treated fairly and not left altogether out in the cold. But there was always the danger that they might be some day frozen out, blood being generally thicker than water, and this is precisely what happened in course of time. But in the meantime the Company prospered exceedingly, and, as it has continued to do ever since, produced iron goods of the best quality. Famous guns and projectiles were also manufactured in thousands, and were used in every ship of the navy and sold in

every part of the world. The following account of the Carron Iron Works from the London *Morning Herald* of 22nd September, 1829, shows how well matters had progressed in the capable hands of the first generation of the happy family:

"CARRON IRON WORKS.—It is gratifying to be able to state that the extensive ironworks at Carron are feeling none of the general depression which at present pervades the manufacturing districts. Upwards of five months ago they received an order for field-pieces, and, though they have since been making at the rate of nearly twenty a week, the requisite number is not nearly completed. Terrible as these mortal engines are, those the Carron Company are at present finishing seem intended to be doubly destructive. Some idea may be formed of their size from the simple fact that when completely ready for use they weigh each fully three tons. A number of howitzers are also in preparation, and, instead of the usual length, from three to four feet, they run from eight to nine, and are intended to throw shells far beyond the usual distance. Some time since, an English foundry received an order for ordnance of the same description; a few of the first made were tested in the usual way by a foreign engineer, and it is said that he was not satisfied, and transferred the order to the Carron Company. At any rate an engineer, accompanied by an interpreter, lately visited Carron, for the purpose of examining these guns. After the usual tests, they were tried by one quite new to the workmen, and the scientific gentleman declared he was highly satisfied, and ordered the work to be completed with all possible despatch. The demand for loom goods is still on the increase. The Company have now four blast furnaces going, making pig-iron from the raw material, and four cupolas in full activity, and the goods ready finished for the market run on the average about 300 tons a week. The Company 'grow' their own workers, as an extensive manufacturer has it, and hence their hands are completely masters of their several departments. They pay no attention to the fluctuations of the markets and the currency; hard as the times are, they have

never mentioned a reduction of the wages, they have more humanity and sagacity than to attempt to extract the last drop of sweat from the poor workmen, and reduce them to the last ounce of oatmeal; and consequently, all who are so fortunate as to be in their employment are comfortable and contented, and take a conscientious interest in the welfare of the concern."

While all this apparent prosperity was attending the Company's operations, the shareholders from 1805 till 1839, one of the most busy periods, were not receiving more than 9 per cent. on their capital, and up till 1850 they sometimes did not get so much.

The manager, Joseph Stainton, and after 1825 his nephew and successor, Joseph Dawson, into whose hands the entire control and management had fallen, continued during their respective lifetimes to pursue what may be called, for the sake of courtesy, an ultra-conservative policy. Immense sums were regularly and privately written off for depreciation or placed to reserve, and large stocks were carefully concealed to be used, if necessary, on a rainy day.

This policy, although disadvantageous to the individual shareholders who wanted to sell their stock or receive larger dividends, was undoubtedly highly advantageous in strengthening the Company's financial position. The quotation from the newspaper of 1829 shows that the Company was able to carry on its business and pay good wages during times of deep commercial distress when less stable concerns had to work on short time or suspend operations altogether. In later times again, after the wave of prosperity in 1872-3 had ebbed and an era of extreme depression had set in that lasted for about fifteen years, Carron was able to face the bad weather undismayed. The good ship sailed calmly on until the clouds had dispersed and the sun was shining again. This was no doubt largely due to the foresight of Mr. Dawson, as it was that dark industrial epoch which finally extinguished all the remaining blast furnaces in the East of Scotland. They had, unlike Carron in the good times, accumulated neither large estates with ironstone nor

large sums to draw upon in the long continued periods of depression to which the iron and coal industry is liable.

This, however, was not the view taken by several shareholders whose stock had been sold at comparatively low prices before 1850, chiefly to the managing family and to the Company itself. After certain facts came to light they raised numerous actions in the law courts for restitution as shareholders or cash damages to compensate them for their loss on selling at too low prices. When these matters were discussed in court many remarkable facts about the internal economy of the Company for half a century were disclosed, into the particulars of which I shall not now enter. The Company, it transpired, had been extremely prosperous for many years, and need not have laid by such large reserves. The shareholders settled the cases extra-judicially, and they or their heirs or representatives were recompensed in the end, when a sum of more than £240,000 is believed to have been refunded them by the Company after several years of litigation.

Some of these ex-shareholders were old people who were easily enough satisfied, and might perhaps have got more if they had been younger and able to fight harder for their rights. Many years ago I was told the story of one who had almost given up the contest as a bad job. One morning he was at breakfast in his house in Edinburgh when the post brought in a letter marked "Carron Coy." He had become so disgusted with the whole shady business that he nearly threw it in the fire unopened; but on second thoughts he broke the seal, and what was his surprise to find inside a cheque in his favour for £17,500! The Adam family who had stood by Carron in its early struggling days were apparently not treated better by the Dawson clique than anyone else, and had likewise sold their shares at low prices; but they too were compensated, and so in the end obtained some reward for their long and faithful services.

These records, if they show nothing else, are interesting as proving that ironmaking had become, by the beginning of the nineteenth

century, a most profitable department of Scottish industry and one capable of great development. Mr. Garbett's dream, mentioned in more than one letter of 1759, of making the Forth Valley the centre of the Scottish iron industry and of studding the little occupied shores of the estuary with blazing furnaces and thundering forges, was not destined to be fulfilled, although a great deal of iron was made in the district at one period.

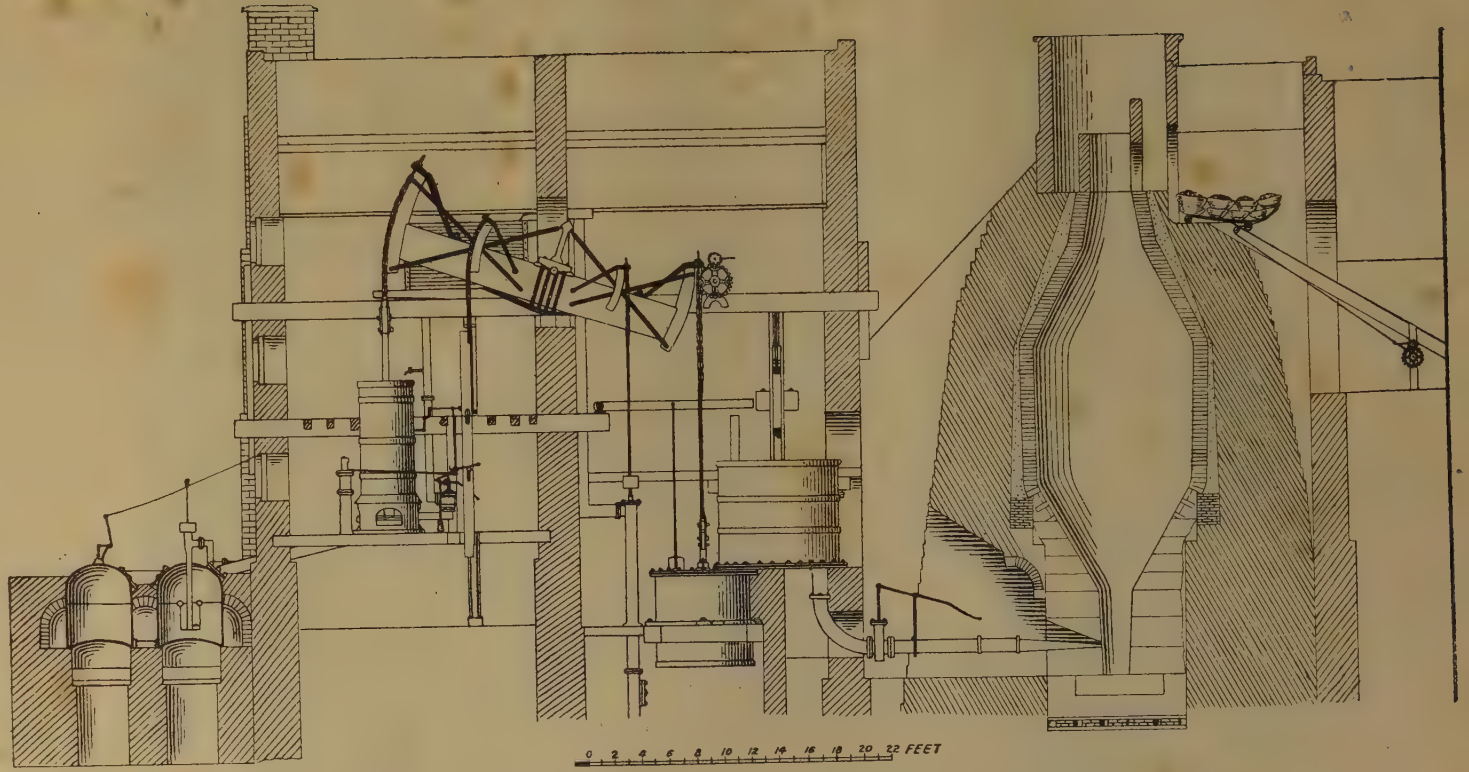
Mr. William Cadell, in association with Mr. Thomas Edington at Cramond, after leaving Carron interested himself in the establishment in 1786 of the Clyde Ironworks in Old Monkland Parish, near Glasgow. The foundation of the great iron smelting industry in the West of Scotland was thus laid, and in the course of a century the manufacture of iron and steel gradually moved from the Forth into the Clyde basin. It there remained and expanded to vast dimensions. The accompanying illustration is taken from an old drawing of the blowing-engine erected at the Clyde furnaces in 1788. It is interesting as a picture of a Newcomen engine without any of Watt's improvements, applied for the first time in Scotland to the direct production of the blast. (See p. 193.)

When pig-iron became plentiful a crop of foundries began to spring up in Stirlingshire under the shadow of the Carron furnaces. In 1819 some enterprising men left the parent establishment and founded the Falkirk Iron Works, which in time became the second largest foundry in Scotland. The Falkirk district became the seat of what was for nearly a century a most prosperous industry, although of late the local iron founding business has tended to decline. In 1880 there were twenty-one foundries in the district, and these with Carron gave employment to 6000 people.[1] They were directly the principal source of livelihood to a population of at least 20,000, and indirectly the means of maintaining several thousands more. Since then Carron has continued to expand, and now itself employs 7000 people, and produces more than 2200 tons of iron every week.

[1] A list of these is given in Nimmo's *History*, 3rd edition, 1880, vol. ii. p. 309.

All this industrial prosperity, that has filled an almost empty district with busy inhabitants, arose out of the brains, capital, and enterprise that were brought into this part of Stirlingshire by four worthy but unwelcome strangers in the autumn of 1759.

In Fife and the Lothians, so long as the supplies of ironstone lasted, ironmaking was for a time an important industry, and large ironworks were established on the shores of the Firth after Carron Company was seen to be a success. In 1792, after a respectful interval of thirty-two years, Carron was followed by the Devon ironworks in Clackmannanshire. The two original furnaces of that establishment were constructed on a remarkable principle. They were excavated out of a cliff of solid sandstone about 50 feet high, situated on the south bank of the River Devon, and the air for the blast was cooled in large chambers likewise hollowed out of the rock. Before the enormous advantages of the hot blast had been discovered by J. B. Neilson in 1828, it was the object of ironmakers to keep the temperature of the air for the blast as low as possible. This may have produced better iron, but not nearly so much of it for the same consumption of fuel as was obtained by the hot blast. The Devon ironworks, which have been dismantled for many years, proved in the end a failure and ruined most of the original partners. Other ironworks were established at Oakley, in the west of Fife, where six large furnaces were built in 1846, and these were followed by the Lochgelly and Lumphinnans ironworks about 1850. On the south shore the four Kinneil furnaces were built in 1853 on the coast a mile west of Bo'ness to smelt the very ironstone of the Bo'ness coalfield that poor Dr. Roebuck had missed eighty years before. In 1855 and 1856 the Almond ironworks were established at Causewayend, where large fortunes were made in a few years. There were at Causewayend three furnaces which were finally closed in 1879 and demolished in 1890. In 1863 two blast furnaces were erected at Bridgeness to smelt the ironstone on the late Mr. Henry



Original Newcomen Blast Engine and Furnace at Clyde Ironworks, from Drawing of 1788.

Cadell's estate of Grange, but these did not remain very long in operation, and were likewise pulled down in 1890.

The quantity of blackband or clayband ironstone on which all these ironworks depended was limited, and the local seams became more or less exhausted after twenty or thirty years' time. The existing Scottish smelters have now to eke out the diminishing native supply with ore imported from Spain and other countries. Foreign competition, almost unknown half a century ago when British ironmasters had everything their own way, has also greatly diminished the prosperity of the Scottish iron smelting industry in recent times.

In the latter half of last century, between 1850 and 1875, the open-topped blazing furnaces brightly illumined both land and sea. Economy in waste gases was little studied when ironmaking was at its zenith, and enormous volumes of useful gas and fiery energy were allowed carelessly to go to waste.

But now only one bright flame, a diminished jet of the surplus gas from the unpicturesque close-topped furnaces, lights up the winter darkness of the valley. All the other blazes on the Forth have been extinct for a whole generation, and few middle-aged people even remember what they were like. The Carron furnaces alone remain hale and hearty, with their natural force unabated after a strenuous and useful career of more than 150 years. They have weathered the vicissitudes and perils of a stormy childhood and a troubled manhood, and now stand forth alone in their mature age, the firstborn and sole survivors of a warm-hearted and once numerous and very brilliant family.

THE CARRON WORKS IN 1912.

To face page 194.

CHAPTER XI.

THE SCOTTISH MINERAL OIL INDUSTRY.[1]

THE Scottish Mineral Oil Industry is to my mind one that bears conspicuous testimony to the *perfervidum ingenium Scotorum*—to the enterprise and inventive genius of our countrymen and to their perseverance and skill in meeting and surmounting the most formidable obstacles in the path of industrial progress. It is a vigorous product of the soil, and owes nothing to extraneous help or state assistance. Indeed, the State, instead of endeavouring to promote, has done as much as possible to discourage the growth of the industry, and has left the Scots severely alone to fight their own battle against terrible odds, or fall in the unequal struggle.

It has been my lot to have wandered among the oilfields of Pennsylvania, Ohio, the Caspian and Burma, and to have seen the liquid fuel spouting high into the air or being pumped like water from the vast subterranean reservoirs. Many a time in these far off places have I turned my thoughts homewards to far other scenes, where nature was less prodigal in her gifts, and refused thus to lavish away her wealth, without demanding in return some tribute of skill and science at the hand of man. While gazing at the oil fountains of the East and West, the foremost thought to rise in the mind of one accustomed only to see the crude and laboriously extracted fluid trickling from the high retorts of the Lothians, is a feeling of despair

[1] This chapter was originally the subject of a lecture delivered at the Dundee Engineers' Institute on 18th Nov. 1910, and at the Royal Scottish Society of Arts on 16th Jan. 1911.

at the apparent hopelessness of the unequal contest. The Scottish oil, in its dry matrix of black shale, has first to be laboriously won—blasted out of mines hundreds of feet deep, hauled or hoisted by machinery to the light of day and crunched into small pieces between strong iron teeth, then carried perhaps some miles to the retorts, where it is carefully distilled and separated from its earthy casing—before it even reaches the condition of the crude petroleum that spouts up in other countries ready made.

It is indeed with a feeling of no little pride that we can point not only to the continued existence, but even to the comparative prosperity in recent years of the Scottish Oil Industry in the midst of such adverse conditions. If, however, our oil is hard to win, the winning of it has engendered a spirit of inventiveness, enterprise and scientific aptitude that might never have been developed under easier circumstances. Necessity—often dire necessity—has been here most conspicuously the mother of invention, and the lessons learned in her hard school are now returning their reward to those of her *alumni* who have studied well and have learned how many valuable things are contained in, and can be extracted from, a lump of oil shale.

The Scottish Shalefields.—Oil Shale is now mined only in one part of Scotland, although it is known to occur in limited quantities in other districts. All the existing oilworks derive their raw material from the area of Mid and West Lothian situated to the west of Edinburgh, between the Firth of Forth on the north and the Cobbinshaw district on the south. The area is roughly triangular in form, extending about eight miles along the base on the north and sixteen miles from the base to the apex on the south. Outside this area oil shale occurs on the Fife coast at different places, and was formerly extensively mined at Burntisland opposite Leith. It is also found on the east side of the Pentland ridge south of Edinburgh in a narrow belt on the west side of the Midlothian coalfield, where it was formerly worked by the unfortunate Clippens Oil Coy. at Straiton and

Burdiehouse. Oil has also, to a limited extent, been obtained from some seams of shale among the Coal-bearing strata in the coalfields of Central Scotland, but none of these are now being mined for this purpose. The productive shale area is shown on the map, p. 36.

Geologically the important shale seams all occur, as we have seen, in the lower part of the Carboniferous formation known as the Calciferous Sandstone Series. This formation, as developed in the Lothians, consists of a vast succession of sedimentary and occasional volcanic rocks extending upwards from the Old Red Sandstone to the top of the upper Coal Measures.

The Oil Shale-bearing part of the formation contains about seven distinct seams or groups of seams of oil shale distributed among beds of sandstone, limestone, marl and ordinary carbonaceous "blaes," argillaceous strata, and impure coal, the total thickness of which as shown on the diagram at page 15, is about 4000 feet.

The strata do not lie in regular order for any distance, but have been thrown into many separate basins, bent and twisted about by ancient earth movements, rent by huge lines of fault and fractures, and invaded at many places by injections of eruptive rock, or pierced by solid plugs of ash occupying the vents of ancient volcanoes. In none of the shalefields do we find the regular horizontality in which the strata were originally deposited. The unravelling of the complicated geological structure of the district was thus for many years a matter of great difficulty alike to scientists in search of knowledge and miners in search of wealth. Even yet there are places that have not been completely explored in which oil shale may be discovered at some future time.

The shallower and richer seams were naturally worked first, but the progress of discovery during the last twenty years has had two important consequences. New shale beds have been discovered in some places, and the existing seams have been opened out in sundry fresh localities. At the same time the advance in scientific technology has led to such additional economies in the processes of manufacture,

that it is now possible in spite of many adverse conditions to work profitably seams which used to be considered too poor to be of any commercial value. Indeed such is the recent progress in the scientific construction of the retorts, that the shale is now made to distil itself with the heat derived from its own residual combustible gases, and no fuel is required except in the temporary process of starting new plant. The waste incondensible gases and tars produced are used for fuel at various stages, and electricity lends its wonderful help in different ways. All these modern economies have given much importance to the question of the future life of the shalefields, in which, no doubt, an immense quantity of oil-, and ammonia-producing shale of various qualities still exists for future development.

Scottish oil shale is a minutely laminated, or amorphous black or dark-brown clay shale containing nitrogen, hydrocarbons and other substances of organic origin derived from the macerated remains of plants and animals. The valuable oil-producing material in the shale has been named *Kerogen* by Prof. Crum Brown, F.R.S. This substance in distillation produces crude oil, which, passing through the refinery, is split up into various useful combinations of hydrogen and carbon, some of which we shall consider afterwards.

Natural Oil.—In a few places a little natural distillation took place in past geological ages, and crude oil as well as mineral wax is sometimes found in small quantities in the rocks ready made. At St. Catherine's, near Liberton to the South of Edinburgh, there is an old well in which the water is covered with a thick skin of petroleum derived from a minute spring exuding from the oil shales below. This is known as the "Balm Well," and was highly valued for its curative properties for centuries before the Edinburgh Medical School had become famous. In the Broxburn district and elsewhere the oil shales have been invaded by local intrusions of heated basaltic rock, and it is a matter of common observation that the cavities and cracks in the basalt contain bitumen, mineral wax, or even liquid petroleum. An actual oil spring was discovered in one of the mines to the Dunnet

shale recently opened at Broxburn. A little dark-coloured thick oil was found trickling out of the cracks in the eruptive rock, and while it lasted was regularly collected and used. Wherever the shale has thus been robbed of its Kerogen it is, of course, rendered worthless, and indeed there are places where large intrusive sills or beds of basalt have entirely destroyed the value of the adjacent shalefield.

Natural gas is occasionally associated with the oil shales, and in some of the original borings in the Broxburn field it escaped in large quantities, and when ignited it lit up the neighbourhood for a time with a brilliant column of flame. Fire damp, the enemy of the coal miner, is however rarely found in quantities in the shalefields, but proper ventilation is, nevertheless, always necessary to prevent the possibility of danger from occasional outbursts.

Oil shale is not peculiar to Scotland, as it is known to occur in England, the colonies, and in other countries. At present extensive shale deposits are being developed in Australia, where several rich seams have been discovered. Scottish engineers, acquainted with the home industry, are in charge of the developments, which we may hope will be attended with success. But the Australians are not sufficiently enterprising in encouraging British capital to develop their country and allowing it to reap an adequate reward, and it does not follow that a seam of shale which might be worked here to the great advantage of the whole community can be profitably mined under the economic conditions and trade-union restrictions now prevailing in the Southern Commonwealth.

History of the Oil Industry.—James Young, or "Paraffin Young," as his friend Dr. Livingstone used to call him, was born in 1811, and began life as a cabinetmaker in Glasgow. He attended lectures on chemistry given by Prof. Thomas Graham, and showed such aptitude that he first became Graham's assistant, and was subsequently appointed assistant to the Professor of Chemistry in University College, London.

He afterwards held an appointment at Tennant's chemical works in Manchester, and while there he received a letter from Professor Playfair (afterwards Sir Lyon Playfair, and later still Lord Playfair) about a spring of petroleum in a coal pit at Alfreton in Derbyshire. On Lyon Playfair's suggestion, Young erected works to refine the petroleum, and thus was born the present-day British oil industry. The crude oil was of the consistency of thin treacle, and the yield of the spring was about 300 gallons a day. Illuminating and lubricating oils and solid paraffin were manufactured in 1848, but in two years' time the spring, like oil wells of more recent date, began to fail, and the infant industry might, in less capable hands, have been left to die a natural death.

Young's scientific mind, however, led him correctly to infer that the oil was produced by the slow natural distillation of coal or coaly substances, and he accordingly set himself to experiment on the artificial distillation of oil from coal.

It may here be incidentally mentioned that Young was not the first to make the attempt to distil coal for the sake of its liquid products. The distinguished, scientific-minded, but unpractical nobleman, Archibald, ninth earl of Dundonald (father of the celebrated naval hero Lord Cochrane, who died in 1831 at the advanced age of eighty-three), spent much time in inventing a process for manufacturing coal-tar at Low Valleyfield in Fife, and took out a patent which, but for his want of business capacity, might have made his fortune. During the process of distillation he noticed the production of a large volume of inflammable gas, and he accordingly fitted a gun barrel to the pipe leading from the condenser. On applying a light the gas burst forth into such a blaze that the illumination was visible from the opposite side of the Firth of Forth at Bo'ness, three miles away. This original accidental discovery of coal gas was afterwards turned to good account by Murdoch, who first introduced it for illuminating purposes on a practical system.[1]

[1] *Vide* D. Beveridge, *Culross and Tulliallan*, 1885, vol. ii. pp. 232-3.

The Boghead Mineral.—Young's important discovery was worked out on quite independent lines, followed up in a thoroughly scientific manner, and attended with perfect success. In 1850 he took out a patent for the low temperature distillation of coal, and after experimenting with various kinds of gas coal, he discovered at Torbanehill or Boghead, near Bathgate in West Lothian, a seam of what appeared to be a kind of Cannel coal of an extremely rich character, which proved entirely suitable for his purpose. Others were experimenting on the distillation of coal and shale in France and Germany, but Young's discoveries were made quite independently of these contemporaneous investigators.

The Boghead Cannel or Torbanehill mineral was not a true coal, but must be now regarded as a remarkably rich kind of oil shale. It occupied a very limited topographical area, and was geologically situated at the base of the true Coal Measures, far above the stratigraphical position of the regular oil shales.[1] It was enormously richer in oil than any of the shales that were afterwards discovered, and has long ago been entirely exhausted. While the richest oil shales yield at most 35 to 40 gallons of crude oil per ton, and have 70 to 75 per cent. of ash, the Torbanite produced 120 or more gallons of oil, and had not much more than 20 per cent. of ash. Such a substance had never been found in Scotland before, and has never been found since, and its enormous value led to a famous lawsuit between the proprietor of the estate, who was only receiving a small royalty on his coal, and the colliery lessee, who was reaping vast and unexpected profits from the new discovery, without paying to the lessor more than the small rent of an ordinary coalfield. Experts were summoned from every quarter to decide whether this was or was not coal, but no consensus of opinion was reached, and the decision of the jury was, that whatever it might be it was one of the minerals included in the lease, and therefore the laird lost his case against the tenant. The case was appealed, and finally the

[1] *Vide* section at page 15.

dispute was settled by compromise, the tenant agreeing to pay a better royalty, which he was very well able to give the lessor.[1]

In 1862 the Torbanite deposit was becoming exhausted and too expensive to work profitably, and the long-continued hunt for oil shale in other districts was begun. In 1864 Young's patent expired, and the industry began to expand rapidly, small paraffin oil works being set agoing in many places. In 1871 there were no less than 51 of these, and the whole production of crude oil rose to 25,000,000 gallons —about a third of the output of the seven works now in operation.

While Young's patent was running, the price of burning oil, the chief product, was 2s. 6d., or even sometimes 3s. 6d. per gallon, but it soon dropped to from 1s. 6d. to 1s. after other competitors entered the field.

The principal competitor came at first from the other side of the Atlantic, and after the discovery of petroleum in Pennsylvania in 1859 and the introduction of American lamp oil here, prices began steadily to fall until at last it had to be sold for less than a quarter of its former price, and the home industry was almost annihilated. After 1873 the oil wells of the Caspian began to contribute to the world's supply, and later the Galician and Burmese oilfields were opened up. These have been followed by others in Roumania, the Caucasus, California, Mexico, the Red Sea coast and elsewhere, during recent years. Rock oil has thus become a common product all over

[1] The evidence in this famous case extended over six days, between 29th July and 4th August, 1853. Thirty-one witnesses appeared for the pursuers and forty-six for the defenders. The whole evidence, with the speeches of counsel and judges, was published in an octavo volume of 412 pages plus 4 plates, and, to anyone acquainted with the subject the record is full of interest. There was a great deal of confusion of thought, and much of the evidence was entirely misleading and beside the mark. In view of our present knowledge, the decision that the Boghead mineral was a coal and not an oil shale must, I think, be considered entirely wrong. The whole matter was put in a nutshell by Professor Ansted, F.R.S., who, on behalf of pursuers, expressed the opinion, "It appears to me to show that the basis of the mineral is undoubtedly clay, and so to differ essentially from coal the basis of which is carbon." He maintained that this was essentially an oil shale and not a coal, and, were the case to be retried in our time, I have no doubt that his opinion would be endorsed by all competent geologists.

the world, and many new oilfields may yet be discovered in remote places. But while this is so, the use of oil fuel has correspondingly increased as a substitute for coal, particularly in places where coal is high-priced or non-existent; and in view of its many advantages the demand is not likely to diminish, but rather greatly to increase in the near future.

Had there been no other shale product than burning oil, the Scottish industry would doubtless have been killed long ago. But the Scots were not to be so easily beaten, and they turned their attention to the production of the other useful substances contained in oil shale, and thus rescued their business from absolute destruction. Necessity had here been most conspicuously the mother of many inventions, some of which will shortly be noticed.

Mining.—The Oil Shale occurs, like coal, at different depths and in seams of varying thickness and quality, and the methods of mining are similar to those employed in the neighbouring Scottish coalfields.

Two methods are in vogue—the stoop-and-room, or pillar system, and the longwall system. The first of these, applicable to seams from 6 to 10 feet in thickness, is the old method of driving a network of roads or "rooms" through the seam, and leaving square pillars or "stoops" between to support the roof. The pillars are afterwards removed, letting down the superincumbent strata in sections suddenly, and if the workings are shallow, creating a great disturbance of the surface of the ground. In the longwall system, generally used nowadays for coal seams 6 feet or less in thickness, the whole working face of the seam is removed at one operation without leaving pillars remaining, and the roof is allowed gently to sink into the "waste" or empty space, a wave of subsidence of the surface following the line of the working face below. Except in a few cases where the seam is under 6 feet thick, this system is not found advantageous in the shale-fields. The shale, being a strong tough material, has to be blasted down with gunpowder, and cannot be easily undercut or "holed" like coal with the pick. Each ton of shale uses about 3½d. worth

of explosives, and the average darg of a shale miner is about three tons.

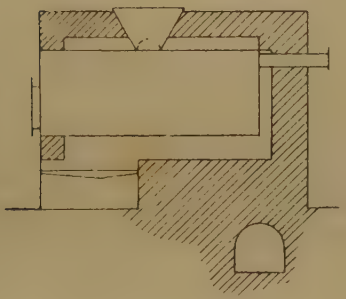
The shale, as we have seen, lies mostly in detached basins, and is generally reached, not by vertical shafts so much as by inclined mines running from the outcrop downwards along the dip of the strata towards the centre of the trough. In some cases the sides of the basins are very steep or even vertical, when the mines change into perpendicular shafts, and special methods of working becomes necessary. Most of the shale is worked downwards from the surface outcrop to what in modern mining are comparatively shallow depths. One of the deepest of the newer mines is that to the Dunnet seam at Broxburn, which slopes at an inclination of 1 in $2\frac{1}{4}$ across the strata, and reaches the shale 720 feet below the surface, but Young's Coy.'s workings have now at one place reached a depth of no less than 1600 feet.

Cheapness and economy in working is all-important, particularly after the passing of the Miners' Eight Hours Act, the establishment of a minimum miners' wage, and other laws designed to promote the interests of the workers both below and above the ground. The most improved systems of electrical endless rope haulage as well as electric winding and pumping are therefore being adopted in all the newer winnings.

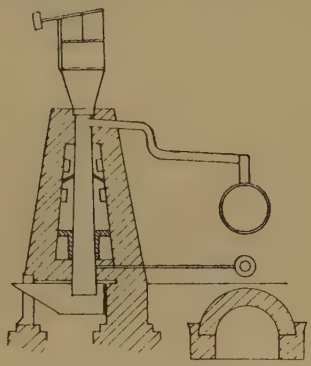
Crude Oil Works.—The history of the shale distillation process is largely the history of the scientific development of the Crude Oil Works, and particularly the story of the development of the retorting and ammonia-recovery plant.

One curious circumstance has been already noted. *Oil shale does not, in fact, contain either oil, oily substances, or ammonia at all.* If it be finely pulverised and treated with any solvent of oil, such as naphtha or ether, it will be found that such solvents entirely fail to extract any oily matter. *Oil can only be obtained after the shale has been heated to a sufficiently high temperature to decompose its Kerogen or oil-producing constituents.* These are broken up and separated so

that they can reunite in order to produce two classes of hydrocarbon, chemically known respectively as the paraffines and the olefines. The ammonia is likewise a new synthetic product, due to the combination of hydrogen with the nitrogen in the shale under the influence of the strong heat of destructive distillation. The hydrogen is not all derived from the shale, but is partly supplied by the steam that is introduced into the hottest part of the retort. This becomes dissociated by the great heat into its elements, oxygen and hydrogen, which are free to enter into new combinations.



OLD HORIZONTAL RETORT IN USE BEFORE 1880.



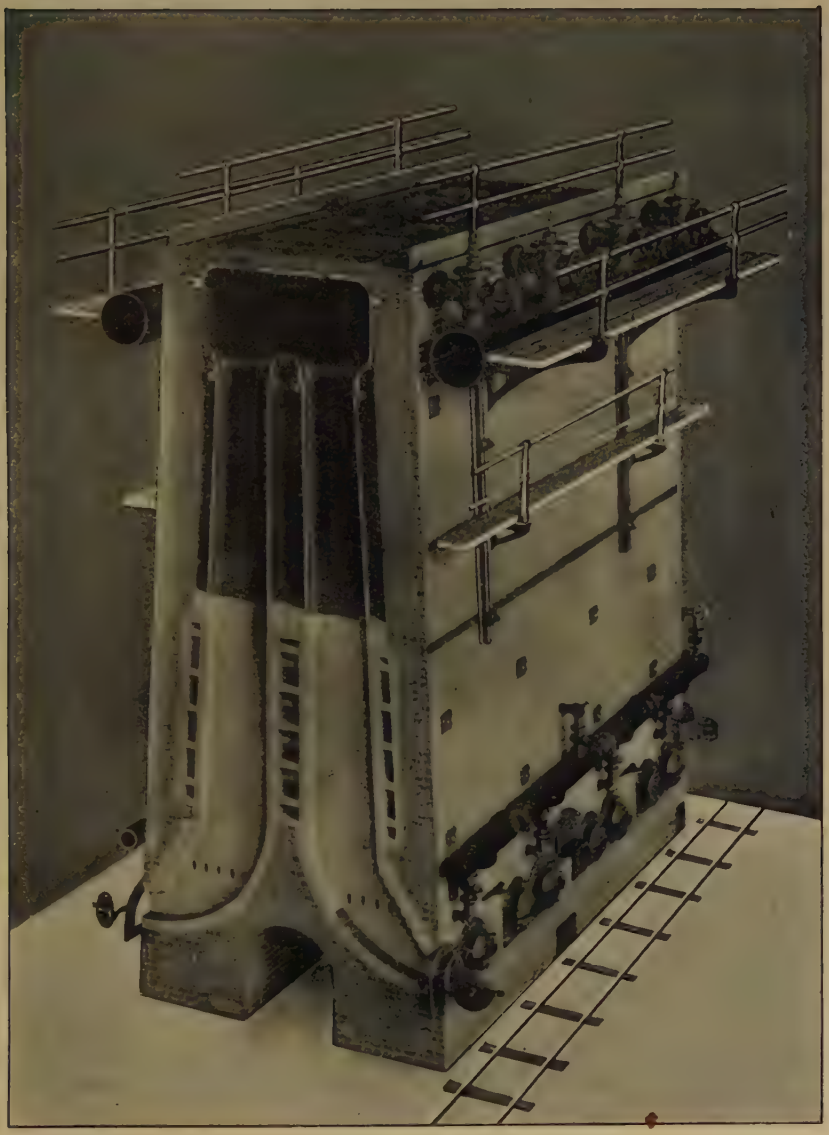
OLD VERTICAL RETORT IN USE UP TILL 1880.

The original retorts, which continued in use up till 1880, were of the horizontal iron type, such as were used in gas works, but the shale was fed by a hopper opening on the centre of the upper side and not at the end. The distillation was conducted at a low temperature, in order to produce as little permanent gas and as much liquid or solid hydrocarbon as possible. Young soon discarded this pattern of retort, which had many drawbacks, and introduced instead one of the vertical type about 10 feet long and a foot in diameter. There was a hopper on the top, from which shale could be dropped in without permitting the escape of gas. The retort was charged hourly, and the spent shale dropped out into a water trough after remaining about eight hours in the heat.

About 1860 steam was introduced into the bottom of the retort, and this led to an immense improvement both in the quality and in the quantity of the products. Various other important improvements were from time to time introduced.

Mr. Norman M. Henderson of Broxburn, to whose useful life and original practical mind the Scottish Oil Industry will ever owe a lasting debt of gratitude, began his long series of valuable inventions by introducing in 1873 a new type of vertical iron retort, in which the spent shale, containing about 12 per cent. of carbon, was dropped into the furnace and acted as fuel for the next charge, thereby effecting a great saving in the coal bill. A further advance was made in 1881, when Young & Beilby's "Pentland Retort" was patented. This retort was much higher than Henderson's, and in its later developments had a height of about 50 feet. The upper part was of iron and the lower part of firebrick, and the heat was derived from vertical coal retorts placed at intervals between the shale retorts. The important feature was the great heat of the lower part of the retort, which received the shale after it had been deprived of its oil in the cooler upper division. The high temperature caused the introduced steam to become dissociated. The oxygen in the steam combining with the carbon in the shale produced carbonic oxide and carbonic acid, while the hydrogen combining with the nitrogen formed ammonia, the excess of hydrogen being afterwards used for fuel to heat the retorts. (See drawing on opposite page.)

Other improvements were afterwards made by Henderson, and in 1895 by Messrs. Bryson, Jones, and William Fraser of Pumpherston. The result of these has been a large increase in the production of ammonia, and at the same time an enormous decrease in the consumption of fuel. Consequently it has now become possible to dispense altogether with the use of coal after the retorts are once heated up, and to conduct the whole subsequent continuous process of distillation with the heat derived from the combustion of the permanent gases produced in the retorts themselves. The



YOUNG & BEILBY'S "PENTLAND" RETORTS, 1881.

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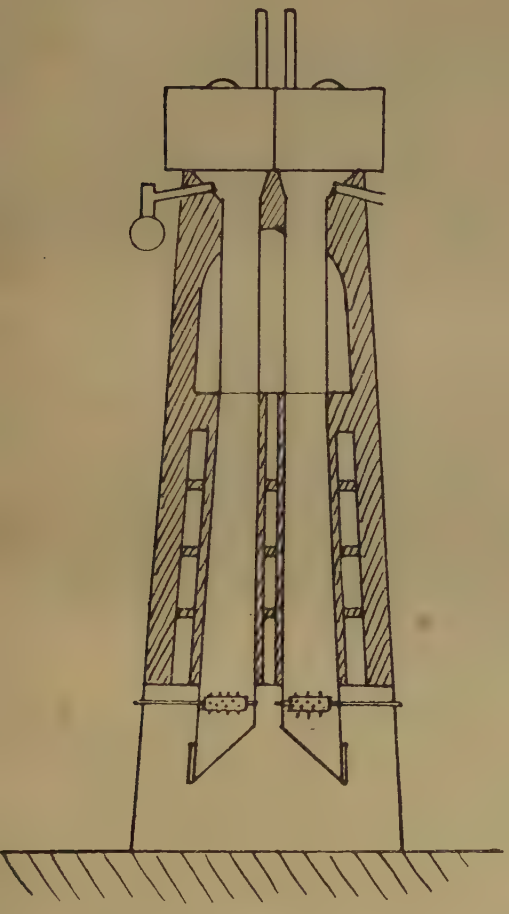
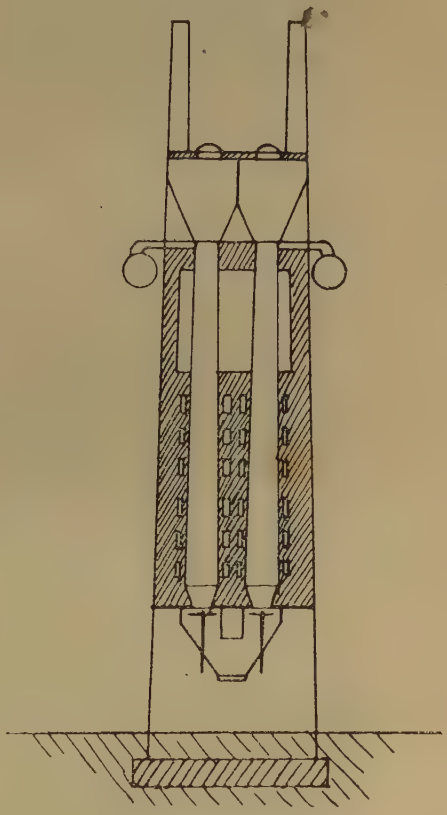
immense importance to the industry of thus being made independent of coal fuel will be at once apparent.



HENDERSON RETORT (LATEST PATTERN), 1901.



BRYSON RETORT, 1895.

The retorts are built in huge blocks or benches over 60 ft. in height, with a hutch line running along the top for filling the hoppers, and another beneath for receiving the spent shale and

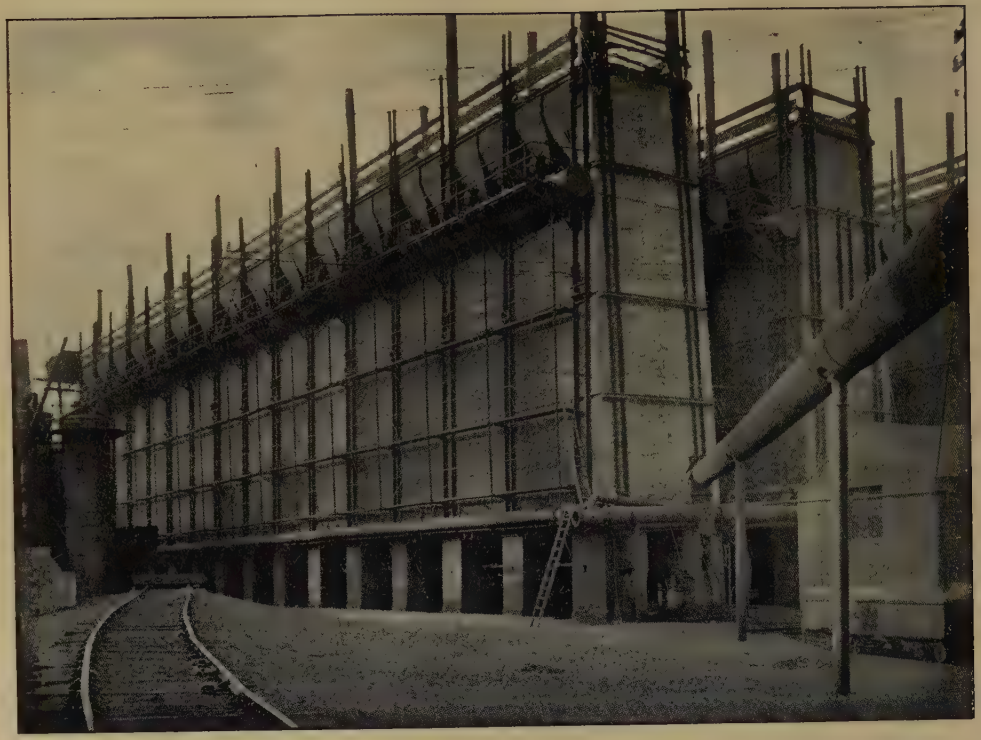
conveying it to the enormous waste bing which forms a conspicuous topographical appendage to every crude-oil establishment.

The shale comes from the mine in large irregular lumps, and passes first to the breakers, whose revolving iron teeth chew it up into pieces suited for the retorts, which can only digest it satisfactorily when reduced to fragments about as large as a man's fist. The largest retorts hold with their hoppers about 15 tons of shale. About 4 tons pass through daily, and the shale remains for 30 hours exposed to the heat which in the upper iron part begins at 1100° F., and increases to 1800° in the brickwork part of the retort as the charge gradually descends. The process goes on continuously, Sunday and Saturday, and never stops so long as the retorts are at work, as it is necessary to maintain a steady temperature and prevent alternate contraction and expansion, which would ruin or greatly injure the massive structure.

The hot steam and gases escape near the top of the retorts into large gas mains, which convey the mixture to the atmospheric condensers made of thin iron pipes. These resemble vast thickets of bamboos in a hot tropical jungle springing from long cisterns that hold the condensed crude oil and ammonia liquor, which trickles down like sap inside the hollow stems.[1]

The crude-oil work has three principal departments, the retorts, condensers, and ammonia plant. The products of condensation are chiefly crude oil and ammonia water. The residual or fixed gas not liquefied in the atmospheric condensers passes upwards through large towers, where it is scrubbed by means of water trickling down in fine streams, and this fluid absorbs any ammonia the gas may still contain. The remaining gases are now drawn off by a rotary exhauster, and blown at a slight pressure through another scrubbing tower, where they are scrubbed a second time, but with heavy oil to absorb any light spirit which has hitherto escaped condensation. The

[1] The accompanying illustrations, showing a bench of retorts and condensers, have been kindly supplied by the Pumpherston Company, the largest of the Scottish oil producers.



BENCH OF RETORTS AT PUMPHERSTON.

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residual permanent or incondensible gas is conveyed under pressure back to the retorts, where it is used as fuel in the heating chambers, and, as we have seen, is often sufficient in quantity to heat all the retorts and entirely obviate the use of coal.

The ammoniacal liquor from the condensers, after being separated from the crude oil, is pumped into an ammonia still, where the ammonia is distilled off by means of steam introduced at a pressure of about 50 lbs. per square inch. The steam, ammonia, and other gases escape at the top of the still, and are conveyed through lead pipes to the bottom of a saturator box containing sulphuric acid. The gases bubble through perforated lead pipes in the acid, with which the ammonia combines to form sulphate of ammonia. The salt is blown out in a pulpy state by a steam ejector as it crystallises in the saturator, and, after being allowed to dry, is crushed and put in bags for the market.

Sulphate of ammonia is of high agricultural value as a source of nitrogen in the soil, and ranks along with nitrate of soda as a fertiliser. The price varies, but last year (1912) it was being sold for £14 or £15 a ton, or a little over 1½d. per lb., and the price obtained meets the whole cost of mining the shale and putting it into the retorts. But for the ammonia, most of our shale seams would in the present conditions of the oil trade be unworkable, and it is the perfecting of the ammonia recovery process which has enabled many shales that were formerly considered worthless to be opened up in recent times, and made to add many years to the profitable life of the industry. It may therefore be truly said that the sulphate of ammonia not only helps to produce good crops of hay and turnips, but that it also fertilises the shale industry itself, and produces crops of oil works and villages in places which, but for its beneficent aid, would be industrially barren wastes.

Refinery.—Oil refining is a chemical process not necessarily confined to the shale industry, and in some cases only crude oil, sulphate of ammonia, and a little petrol are produced at the works near the

shale mines. The two departments are technically quite distinct, and a refinery may, and sometimes does, treat other things besides crude shale oil.

The crude oil is distilled many times in order to separate successively the different ingredients which have varying degrees of volatility and specific gravity. It flows out of the stock tank or reservoir at the fountain head of the refining process, to crude-oil stills, where at the first operation it is separated into green or crude naphtha, green oil, and a small quantity of what is known as "still" coke. The last product is the solid residue left in the stills after the volatile hydrocarbons have all been expelled. Still coke is the first by-product of the refinery, and is sold as a domestic fuel. It is a spongy glossy substance, very useful for drawing-room fires, etc., as it is perfectly smokeless, and leaves practically no ash in the grate.

At the earlier stages of the distillation another important product is obtained in small quantities. From the permanent gas in the first distillation in the crude-oil work, most of which is used as fuel, a little shale spirit can be extracted, and this again can be distilled so as to yield motor spirit and crude naphtha. Some motor spirit is likewise obtainable in small quantities from the gas evolved during the first distillation of the green oil in the refinery. Motor spirit is thus one of the useful products first obtained from oil shale, and might no doubt be manufactured in larger quantities if the price warranted the expense and trouble involved in its production.

The distillation in the stills is assisted by superheated steam, and there is at each distillation a certain evolution of gas, most of which, being permanent, is used for fuel, but, as has been stated of the permanent gas produced at earlier stages, a little of it can be condensed and refined into motor spirit.

The green or crude naphtha is next agitated with sulphuric acid, and afterwards with caustic soda, and after another distillation produces refined naphtha, light oil, and a small quantity of tar, which can be used as fuel.

ATMOSPHERIC CONDENSERS FOR CRUDE OIL.

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The green oil is likewise treated with sulphuric acid, and then with caustic soda. The acid oxidises some of the ingredients, and causes their separation in the form of a black tar, which falls to the bottom of the tank and is run off.

The acid tars from the various stages of refining are subsequently washed, the recovered acid being used in the ammonia house, and the tar, after being neutralised with the soda tars, is used as fuel for heating the stills. The soda is also recovered and used again.

After the acid and soda treatment, the green oil, by a second distillation, is "fractionated" principally into light oil and heavy oil containing paraffin. The light oils are treated with acid and soda, and distilled once. A small portion is distilled twice in order to produce the following brands of oils at Broxburn and at other works:

	Sp. Gr.	Flashing Point.
Petroline - - - - -	0.800	110° to 120° F.
No. 1 Paraffin Oil - - -	0.806	120°
Lighthouse Oil, - - -	0.810	150°
Marine Sperm, - - -	0.830	230°

In distilling these products much gas is evolved, from which motor spirit and illuminating or heating gas is produced.

The heavy oil and paraffin are next separated, by cooling and filter-presses, into blue oil and crude solid paraffin scale. The blue oil is treated, distilled, and fractionated into intermediate oils of sp. gr. 0.850 to 0.870, used for gas making, fuel, and other purposes, and into heavy lubricating oil of sp. gr. 0.865 to 0.895. A little gas, motor spirit, tar, etc., is here also produced.

The crude paraffin scale, a yellow, greasy, scaly substance, is purified by a process of sweating pans in a hot chamber, which expels the oily residue from the solid paraffin. The paraffin, after a second sweating, is melted and clarified with charcoal, when it emerges from its long process of education in a pure and beautiful condition ready for the market. Paraffin wax has no taste, smell, or colour, and resists the action of the strongest acids. It is manufactured with various degrees of hardness adapted to its various uses. The softest wax or

match paraffin has a melting point of 100° F., and the hardest, used for candles, both for sacred and secular purposes, melts at 130° F. The candle factory is one of the most beautiful and interesting departments of our shale industry, which no visitor should neglect to see.

This very abbreviated outline of the process of manufacture, which, by the way, admits of a certain amount of variation in different works, where refinements may be carried to greater or less lengths, will no doubt be a little difficult to grasp at first. But the general scheme may easily be followed by reference to the appended diagram. This is drawn up on a somewhat genealogical method, all the products being descended from the original ancestor, a ton of oil shale. The diagram is intended also to give an idea of the relative sizes of the descendants. By far the largest of these is the spent shale—the prodigal son of the family—a veritable "waster," cumbering much good ground at every oilwork. No profitable use for it has yet been found. An American visitor to Broxburn suggested, as his supercilious countrymen are fond of doing, that Scotland being a very small place, the spent shale-heaps might best be emptied round the coast to increase its size. So they might, no doubt, if the American oil left us enough profit to let us thus expand our little country, but that is not yet, I am afraid. It will be a long time before the oil wells dry up and our land values increase enough to place us in the happy position of saying to the shale mountains, "Be thou removed and cast into the sea—to make more room for our prosperous and overflowing population."

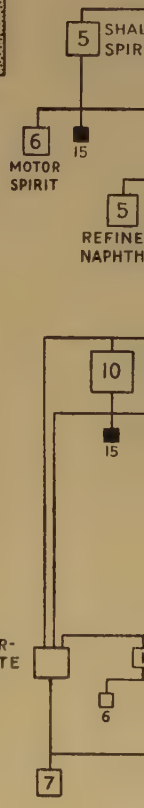
The crude oil extracted from a ton of shale weighing 2240 lbs. is only about 260 lbs. in weight, and the ammonia sulphate, the joint offspring of shale vapour and sulphuric acid, only about 40 lbs., or 300 lbs. in all. During the process of distillation there is always a considerable loss, and the diagram indicates the enormous labour and skill that are required to produce the marketable products, the goal of the refinery.

DIAGRAM ILLUSTRATING
PROCESSES OF MANUFACTURE
IN THE

SCOTTISH MINERAL OIL INDUSTRY

COMPILED BY. H.M. CADELL 1913.

WASTE
SPENT SHALE
75%

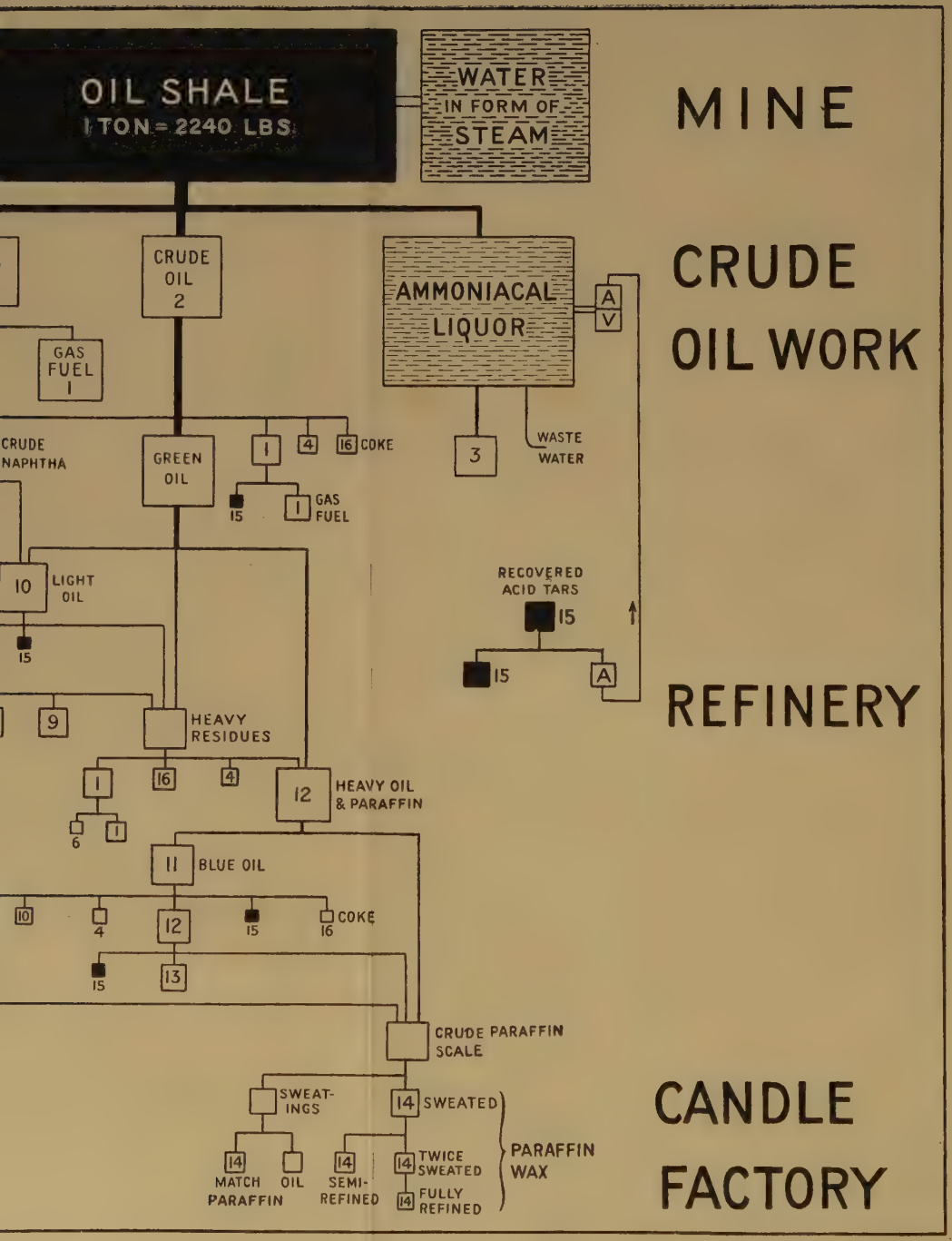


OIL SHALE PRODUCTS

1. GAS (MAINLY USED AS FUEL)
2. CRUDE OIL
3. SULPHATE OF AMMONIA
4. CHRYSENE
5. NAPHTHA
6. MOTOR SPIRIT OR PETROL
7. GAS OIL
8. BURNING OIL Nº 1
9. Dº Dº Nº 2
10. LIGHT OIL
11. BLUE OIL
12. HEAVY OIL
13. LUBRICATING OIL
14. PARAFFIN WAX
15. TAR
16. COKE

A = SULPHURIC ACID RECOVERED FROM TARS.

V = VITRIOL OR PURE ACID ADDED TO A IN MAKING AMMONIA SULPHATE.


OIL SHALE
1 TON = 2240 LBS
WATER IN FORM OF STEAM
MINE
CRUDE OIL 2
AMMONIACAL LIQUOR
A V
CRUDE OIL WORK
GAS FUEL 1
CRUDE NAPHTHA
GREEN OIL
1 4 16 COKE
15 1 GAS FUEL
3
WASTE WATER
RECOVERED ACID TARS
15
15 A
10 LIGHT OIL
15
9
HEAVY RESIDUES
1 16 4
12 HEAVY OIL & PARAFFIN
6 1
11 BLUE OIL
10 4 12 15 16 COKE
15 13
REFINERY
CRUDE PARAFFIN SCALE
SWEAT-INGS
14 SWEATED
14 MATCH PARAFFIN
OIL
14 SEMI-REFINED
14 TWICE SWEATED
14 FULLY REFINED
PARAFFIN WAX
CANDLE FACTORY

Oil-Shale Products.—It is beyond my power to exhaust the catalogue of the oil-shale derivatives and their uses. The following are some samples of the long and useful list :

1. Sulphate of ammonia as a nitrifier of the soil is one of the best known fertilisers in agriculture. Directly, it aids in the production of all kinds of graminiferous and leguminous crops for the food of animals and man, and indirectly in the production through these crops of beef, mutton, milk, sugar, and wool.

2. The volatile shale spirit from the permanent gas propels motor cars, motor boats, or airships, and thus carries us swiftly over land and sea, or even through the air to our destination in distant places.

3. The naphthas are used for burning and for enriching gas, also as solvents in the linoleum industry, for paints to beautify and preserve for cleaning our soiled garments, and for all kinds of rubber goods to keep us dry, and electrical apparatus to give us light and power.

4. The burning oils with high flash-point go to remote light-houses to guide our ships over the dark and stormy waters, and also light up our dwellings where gas and electricity are not available. The lightest lubricating oils are largely used for jute batching in Dundee, and the heavy oils for the wheels of vehicles and machinery. They also provide fuel for the boilers of the merchantmen that feed and the men-o'-war that defend these islands.

5. The paraffin wax produces snow white candles to light humble dwellings, palaces, sacred shrines, and holy altars ; matches and vestas to kindle the meditative pipe of peace, or the fire on the domestic hearth. Physicians employ it for dressings of wounds and ointments, and under the form of vaseline it is used to lubricate the human frame both externally and inside, while good housewives find paraffin the best preservative for covering the delicious jams made in summer and stored away for the family's winter use. The very bees in the hive also find a use for it. They build their combs on thin plates of paraffin wax provided for them, all neatly stamped with the hexagonal pattern of the cells, and the labour thus saved in collecting wax

enables them to improve the shining hour and produce more honey. Indeed the very honey they suck from the purple clover and fragrant flowering beanfields may be partly derived from sulphate of ammonia from oil shale sprinkled thinly over the receptive soil.

6. The black tars, when not burnt for fuel, are used to protect structures from the weather and for the production of asphalt for roofs and pavements. Quite recently a new and increasing market has arisen for this by-product, in consequence of the invention of tar-spraying of country roads, to prevent mud and dust and to produce a good surface for motor traffic.

In short, from black tar to white wax and limpid spirit, there are few products of oil shale that are not found ministering in some way or other to the needs or luxuries of every department of civilised existence.

Commercial and Social Aspect.—The golden age of the Scottish oil trade was the decade from 1860 to 1870, before the gigantic tyranny of the Standard Oil Company had been established and the foreign oil began to swamp the native product. In 1860 there were six oil works, and in 1870 these increased to 90, but ten years later the number had fallen to 26, and in 1890 to 14. Under the "beneficent" influence of Free Trade, or rather Free Imports, the number dwindled down to nine in 1900, and at the present day only seven have been able to survive the very unequal struggle for existence, and the ruins of those which have fallen in the fray lie scattered in melancholy piles over all the district. During the sixty years' life of the industry altogether about 120 works have been born and died, some without even paying a dividend. The foreign invasion came in successive waves, and each wave dashed against a fresh quarter of our defences, and unless our inventors had directed their energies to the repair of the successive breaches, the industry would have long ago been absolutely extinguished. In all this long struggle the loss of capital to the shareholders of the different works has been estimated at not less than £1,750,000, not to speak of the loss to the multitude

of tradesmen and workpeople directly or indirectly dependent on the prosperity of the industry.

No doubt the producers at times have also competed against one another, and companies have been floated which should never have been set agoing, but the total quantity of oil produced is small as compared with that imported, and it is the price of foreign oil that really rules the market. During the fourteen years of Young's patent, the retail price of refined burning oil was about 3s. 6d., but at the end of 1911 it was being retailed to the consumer at only 4½d. a gallon—less than half the price of sweet milk—no doubt greatly to the advantage of the consuming public, but very little to that of the Scottish producer. Since 1911, however, prices have happily begun to recover again without serious injury to the consumers.

As matters stand, seven shale companies survive. Three of these have only crude works, and the remaining four have refineries in addition. These works, known respectively as Young's, Broxburn, Pumpherston, Oakbank, Dalmeny, Philpstoun, and Tarbrax, have between them a capital of about £2,000,000, and employ about 8100 workpeople, half of whom mine the shale and the others work on the surface. Besides these there are many officials and salesmen in offices all over the country, and the total number of people depending on the industry is well over 20,000.

Three million tons of shale are raised annually, out of which is produced 72,000,000 gallons of crude oil and over 50,000 tons of sulphate of ammonia. About 75 per cent. of the crude oil is converted into finished products. Against these figures of home production the imports of petroleum into the United Kingdom amounted in 1911 to nearly 366,000,000 gallons, or five times as much as the crude oil we produce. The principal product, the burning oil made at home, only constitutes about 10 per cent. of the total requirements of the United Kingdom.

The existing oilworks, although very much fewer in number than those of thirty years ago, are all much larger concerns and raise every

year far more shale than was ever produced before. Indeed, during the last decade the output of the mines has increased from two to three million tons, or by about 50 per cent. This is due largely to the improvement in the retorts and in the ammonia-recovery process, whereby many shales formerly regarded as too poor to work for oil alone can now be utilised for oil and ammonia combined. Indeed, there are seams of shale comparatively rich in oil in some districts, which might formerly have been utilised, but, on account of the small quantity of ammonia-producing constituents which they possess, they are not worth the cost of mining in the present state of the oil market.

To carry on the industry with success, every possible economy and labour-saving apparatus must be employed, and a sufficiently large output must be maintained to meet the normal oncost and reduce the proportion of oncost expenses per ton.

The shale miners' wages are ruled by those of the coal miners, and the minimum wage with the legal maximum of eight hours daily work underground applies to shale as well as coal mines. There is thus an irreducible minimum below which shale cannot be raised under the recent labour legislation, and it is not easy to see how any further economies can be effected in the surface arrangements and the refinery, every process having been already reduced to a degree of scientific efficiency which cannot apparently be much further improved upon.

No doubt outsiders, observing that the Pumpherston Oil Company in 1910 succeeded in paying as much as 50 per cent., and other companies dividends of 10 to 15 per cent., may consider the industry in an exceedingly safe and prosperous condition. But this is only because the directors of these companies have for many years adopted the wise policy of keeping down the capital account by reserving a large part of the shareholders' profits in former years, and defraying new plant and developments out of the sums which less well-managed companies would have paid away in dividends. These companies' boards surely deserve to be rewarded now for the foresight and

financial capacity, no less than for the scientific skill and aptitude which they have displayed in the past.

Many other companies have gone under altogether or have been forced to write off a large part of their share capital in order to be able to show a fair dividend. Were the maintenance of efficiency to be relaxed by any of the companies or the severity of the foreign competition to increase still further, the trade would again suffer acutely or might even be brought to the brink of absolute ruin.

Topographical Effect of the Oilworks.—The Oil-Shale Industry has produced a notable physical as well as a social change in the district where the mines are situated. Much of the ground which they occupy was, half a century ago or less, a poor agricultural country with a cold clay soil, and only a small farming community. It is now covered with towns and villages with a large assessable rental and a regularly employed industrial population.

But the most conspicuous, and what may prove perhaps the most permanent physical change, is to be observed in the steady growth of small ranges or groups of flat-topped hills of red material, 200 or even 300 feet high, with steep sides covered with screes, closely resembling in form the extinct cones of eruption on the plain of Mexico and other volcanic regions.

Black rubbish bings can be seen in any deserted colliery district, but in comparison with the spent shale bings of the Lothians these are as molehills to mountains. The spent shale when emptied out, warm from the retorts, is dark grey or black at first, but it becomes oxidised in time and assumes a bright brick-red tint, in striking contrast with the drab coloured soil, and akin in hue to the tiles of the old farm houses. But these hills resemble volcanoes in more than the mere outward form. They are real "mountains of accumulation," and, like volcanic ash cones, have been thrown up from holes in the ground close to the place they occupy. They have also been subjected to great heat; in fact, they have been actually

thrown up as ashes, and may often be seen sending up small clouds of smoke and steam into the air. In the far distant future, long after they are quite cool and disintegrated with the weather, geologists may well speculate on their origin. Indeed, the puzzle may become more difficult to solve when and if it is found by our successors, on exploring in the strata below, that some of these ashy cones actually stand on or near the top of real volcanic necks piercing the underlying Carboniferous rocks and sinking for unknown distances into the bowels of the earth.

It is also a matter of interest to speculate on the size to which these "human volcanoes" will grow before the shalefields are exhausted, as exhausted they will be some day. The Broxburn Company raises, for example, every year 500,000 tons of shale, three quarters of which are heaped up as waste residues on the spent shale bing. If, for the sake of argument we suppose that each ton of shale raised from the mine produces $1\frac{1}{5}$ cubic yards of spent shale (probably it produces a good deal more), there will be added to the heap annually 600,000 cubic yards at least. This is equivalent to a column on a base one acre square, with a height of 360 feet. The Great Pyramid of Gizeh, the most wonderful monument of antiquity, built by Cheops about 5600 years ago, is 451 feet high and contains 3,057,000 cubic yards of stone, covering an area of 13 acres. Herodotus says it took 20 years to build, and 100,000 men —slaves, no doubt—worked for 3 months every year on its erection. Now, if the material had been spent shale, the Broxburn Oil Coy. could have made as large a heap in five years, with less than 2000 men working regularly for good wages, and making in addition a large quantity of far more useful things than monumental pyramids.

Or again, taking all the shale works together, we find that every year among them they are emptying down material equal in bulk to a mound somewhat larger than the great pyramid of Cheops.

The accompanying illustration shows the "human volcano" that is quickly rising to vast dimensions close to the old castle of

NIDDRIE CASTLE ON THE SITE OF A CARBONIFEROUS VOLCANO.

Becoming overshadowed by a "Human Volcano" of Spent Shale.

To face page 218.

Niddrie, near Winchburgh. The ruined tower stands on the top of a neck of one of the old Carboniferous volcanoes described in a former chapter. The flat-topped mound in the background is only ten years old, and for the last five years or so it has been increasing at the rate of about 1000 cubic yards daily or 365,000 cubic yards every year. In another decade its dimensions will be more than doubled.

These enormous mounds have all come out of correspondingly large subterranean cavities, spread over comparatively wide tracts of country. When the pillars in the workings are finally removed, the surface sinks or falls in, and thus in a completely exhausted shalefield or coalfield the whole face of the country is sometimes lowered a good many feet. Some districts, where several superincumbent seams have been worked in succession, have thus been lowered 20 feet or more, and the whole contour of the land has been altered. Before all the shale seams of the Lothians have become exhausted, the surface will thus have undergone some notable changes, and no human or natural operations can ever restore it to its former state.

Future Prospects.—The oil-shale fields are, however, not nearly exhausted yet, but from what has been said, although there may be an abundance of shale at greater depths capable of being made a source of useful employment to a large population for many years, unless the external conditions remain favourable the risk is always present of danger from unfair and unequal foreign competition.

It is well known that the policy of the Standard Oil Company has all along been, at home and abroad, to endeavour, by underselling or "freezing out," to bring about the ruin of all competitors, even at a considerable initial sacrifice, and so gain the complete control of the trade, and, after accomplishing this end, to raise the prices on the consumers and recoup the sacrificial loss. In this policy that unscrupulous and relentless combination has in some fields been quite successful, but, as we have seen, our native industry has managed to survive, and let us hope it may not only survive but prosper while any shale remains to be worked.

Under the existing fiscal system of this country, to which many people fanatically adhere in all circumstances, struggling but important British industries may be and have been destroyed by foreign competition reducing prices below the remunerative level. To the non-fanatical and unpolitical onlooker the commonsense view of the question would be this: since there is now a legally established minimum wage and a legally fixed maximum of working hours besides other restrictions on the industry that all tend *to protect the operatives*, there should likewise, to follow the system to its logical end, be a legalised minimum price *to protect the product*, and thus enable the industry to be carried on in the face of undue foreign competition. That seems only commonsense, and were some such system adopted, more encouragement would be given to some old industries and to the establishment of new ones in this country.

The wages of shale miners, as shown by Mr. Fraser's chart on next page, approximate to those of coal miners. I have compiled from authentic sources another diagram, giving prices of coal as well as miners' wages for half a century up till the end of 1911. It will be seen from this that a sliding scale has been practically in operation during the last 50 years, by which the coal miners have shared some of the losses as well as the profits of the trade. But in the oil industry, the first diagram shows that while there was extreme depression in 1910 and 1911 the wages did not share any of this, but were maintained at a steady level, higher even than that in the period 1901-1906, when the price of the products was not nearly so low.

At this very time, when the industry was struggling with low prices and high wages, the State thought fit, not to help the trade, but, on the contrary, to impose an excise duty of 3d. a gallon on native petrol, as well as a customs duty quite properly imposed on the far larger quantity of imported spirit. In this way about £16,000 was drawn from the unhappy Scottish oil works.

No doubt the trade has its ups as well as downs, and the industry

Chart showing movement of Coal and Shale Miners' Wages.

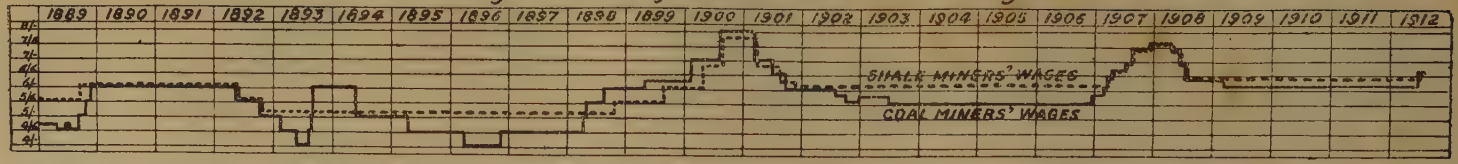
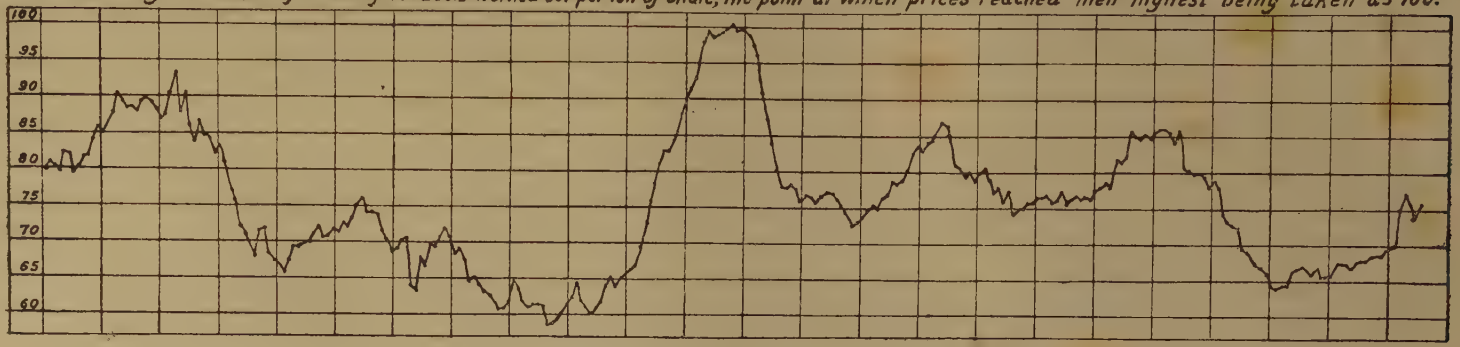


Chart showing movement of Prices of Products worked out per ton of shale, the point at which prices reached their highest being taken as 100.



The extraordinary fluctuations in the prices of the shale products during the last twenty-three years are well exemplified in this diagram. It was compiled by Mr. Wm. Fraser of the Pumpherston Oil Coy., whose strenuous life has been devoted to the success of this great concern and to the development of the Scottish Oil industry in general. The diagram also shows the average wages of coal and shale miners during the same period. In 1910 and 1911, it will be observed, prices of the oil-shale products fell to a very low point. Some well-established and usually prosperous companies, such as the Broxburn, were thus unable to pay a dividend on their ordinary shares in 1911. Had it not been for the sulphate of ammonia the outlook for the industry was then extremely dark. Happily, 1912 has been a more prosperous year, but there is always a considerable risk for which in any well-ordered industrial state there should be a corresponding reward to those who undertake it.

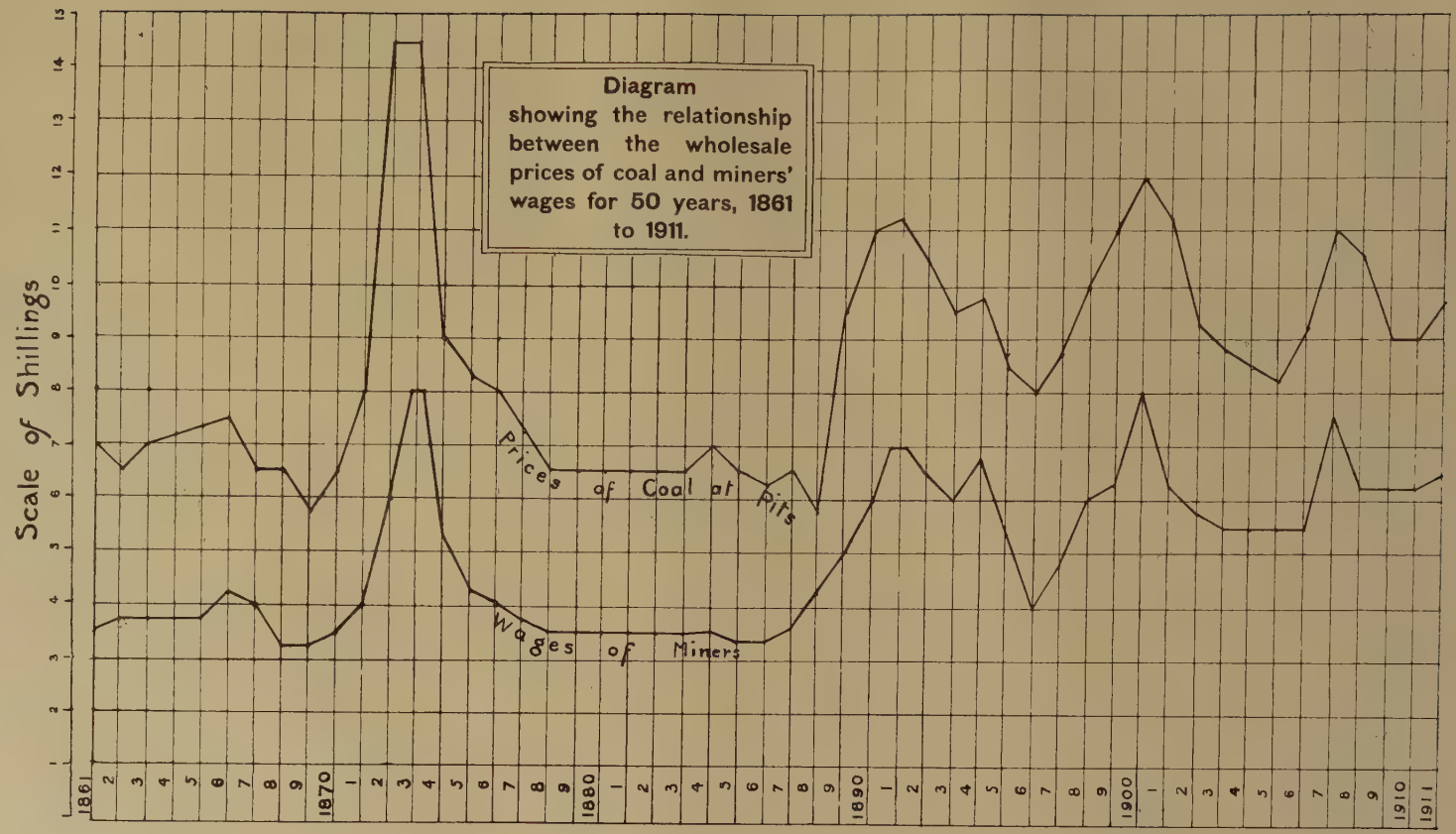
in 1912 could perhaps stand this new impost. But these chapters are meant, while treating the subject historically, also to point out a few ways in which the future welfare of the country can be fostered. One thing is certain. The country is sadly in need of more rural rather than more urban sources of occupation, and as shale works cannot be taken into large cities like spinning mills or iron foundries, the oil industry must always be included in the category of rural occupations.

But we have surely come to a miserable pass when we have to speak of a rural industry like this having *to stand* a tax at all. In other British possessions, instead of taxing it the governments actually allow a bonus on oil produced locally.

These are the places to which the best of our people are emigrating, places that are ruled on commonsense principles, where new and possibly precarious industry is fostered instead of being discouraged, and statesmen, with the country's true welfare at heart, do not allow themselves to be blinded by doctrinaire principles that have outlived their usefulness.

There is plenty more oil shale in Scotland, mostly, however, at considerable depths, and derelict fields exist that might be reopened and made to contribute to the fuel supply of the navy and merchant service. But until a change takes place in the public attitude to the fiscal question, and more commonsense with less of party politics comes into vogue, there seems little prospect of much being done publicly to promote the development of this very important department of rural enterprise.[1]

[1] The writer, it may be explained, is in no way financially interested in any Scottish oil company, and can, therefore, take a perfectly impartial view of the whole subject. From an outsider's academic point of view it seemed to him very unjust that, when the industry was in distress in 1911, the State should not only lay fresh and vexatious burdens on the working of the mines, and draw a large revenue from ordinary rates and constantly increasing taxes, but should also seek to make a profit at the expense of the struggling oilworks by imposing the new duty on their small production of motor spirit, the natural effect of which was to increase the difficulty of selling it.



This diagram of the price of coal per ton and miners' average daily wages shows approximately how, independently of legislation, a natural sliding scale of pay has been in operation in some West Lothian collieries for half a century. It also illustrates the recurring fluctuations of depression and prosperity that characterise this industry. During the long period of depression in both the coal and iron trades between 1874 and 1889, coal mining was generally unremunerative, and all the blast furnaces in the Forth district, except those of the Carron Ironworks, were finally extinguished (see p. 189).

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CHAPTER XII.

LAND RECLAMATION IN THE FORTH VALLEY.

WHEN the last upheaval that raised the Carse lands above sea-level dried up the shallow alluvial shores of the valley above Stirling and greatly narrowed the estuary as far down as Bo'ness, it left several thousands of acres of foreshore lying bare at low tide which might all have been converted into dry land had the movement only been continued a few feet further. No doubt the mud brought down by the river has been steadily, if slowly, filling up the valley in later times, and making it both shallower and narrower in some sheltered places, but the process of natural accretion is an extremely slow one, and the progress is not easily measured.

While other industrial developments were taking place during the general awakening of Scotland in the end of the eighteenth century, the idea of improving the shores of the estuary, and gaining some of the shallow foreshores from the sea, began to attract the attention of various enterprising people.

It may here be explained that the rise and fall of the water is about 18 feet at ordinary spring tides, and between high and low-water level the foreshores above Queensferry extend altogether to a little more than 8000 acres. In 1800, before any considerable reclamations had been carried out, this area was about 9000 acres. A large part of this tract is covered by 10 feet or less of water at ordinary spring tides, and the fine alluvial mud impregnated with organic matter makes rich, strong soil when dried and freed

from the small quantity of salt it contains, by a short period of exposure to the weather.

The prospect of thus adding to the size and value of their estates long ago induced riparian proprietors to consider and carry into execution useful schemes for reclaiming the useless mud-flats in their vicinity. But during the last thirty years the value of agricultural land has so fallen and landowners, both good and bad, have all been so penalised and threatened with destruction by unsympathetic or even positively malignant politicians, that every discouragement has been given to such enterprise, and the whole community has suffered in consequence. If such works are not undertaken by the landowners themselves, or at least promoted by them, there is small likelihood that they will ever be carried out at all.

It is often assumed nowadays that a landowner is actuated by purely selfish motives in promoting any work which is to benefit his own property in the first instance, but his accusers are apt to forget that every proprietor is not a born tyrant, and even if he is, a laird cannot improve his land without at the same time promoting the welfare of the people who live on it. The more good land there is the greater will be the permanent demand for labour to cultivate it, while the temporary demand for unskilled labour to reclaim it from the sea, from the barren peat moss, or from the stony wilderness, will always give a great deal of useful employment to the people in the vicinity. Everyone who makes the proverbial two blades of grass to grow where there was but one before is a public benefactor, whether he personally derives some additional benefit from the second blade or not, and his enterprise and outlay are surely worthy of a fair reward. Soldiers and statesmen who add to the King's dominions across the sea at the cost of immense labour, money, and suffering, are loaded with rewards and honours; and is not the private and unostentatious individual at home also worthy to be called a hero and a patriot of the best kind, who uses his brains and money in laboriously overcoming the wild forces of nature, and snatching

good land from the clutches of the stormy sea or the savage morass so as to increase the size of the habitable parts of the country without shedding a drop of blood or wasting a penny of public money? War against mankind and good property is necessarily more or less destructive and economically wasteful, but war against the wild forces of nature is, from the point of view of humanity, a constructive, and in every way a useful, operation worthy of the attention of all statesmen who have the real welfare of the country at heart. The reclamation of the Blairdrummond Moss a century ago by Lord Kames, his son, and grandson, was, for example, the work of patriots of the best kind. On them the blessings of a whole community were poured, and the good land they opened up is still supporting a thriving population. But there is other equally rich soil alongside of it lying buried under a quaking bog hundreds of acres in extent, which might still be attacked and reclaimed by energetic men with brains and public spirit had they any encouragement to persevere in the good work.

Happily for this generation, the attention of the State has been drawn to the question of land and foreshore reclamation in the British Islands by the recent investigations of the Royal Commission on Coast Erosion, etc., whose elaborate and voluminous report deals exhaustively with the whole matter. The British coasts are being washed away at some places, and the geological process to which I have referred, that will ultimately reduce the whole land to the level of a flat sandbank, is in active operation at these unfortunate spots.

But it is comforting to read from the Report that the surface of the United Kingdom is not diminishing on the whole, but steadily increasing. This is due to the fact that far more land is being reclaimed from the sea in the sheltered estuaries and inlets which were produced by the submergence of the old river valleys after the Ice Age, than that which is being washed away at other places. The Firth of Forth is one of these happy and secluded valleys, but it might be made still happier if more reclamation

works were instituted and its industrial capabilities were better known.

The subject of the Report is well worthy of more public attention and discussion than it has as yet received, and since it is much too solid and voluminous a document to be studied except by a few specialists, and is not very accessible to, or likely to be seen by, many of the reading public, I shall now briefly describe in a connected and amplified form the evidence I laid before the Commission relating to the reclamations that have been made here during the last century, and I shall quote *in extenso* the part of Vol. III. which deals with these works and the possibilities of future acquisition of land from the sea in the Forth estuary.

The reclamation of the Blairdrummond Moss is a different subject outwith the scope of the Royal Commission, but as it also relates to the development of the district and the welfare of its inhabitants, and has, moreover, a great deal of historic and industrial interest as well as a direct bearing on some present-day industrial questions, I shall devote to it the whole of another chapter.

Foreshore Reclamations.—Between Bo'ness and Higgin's Neuk at Kincardine Ferry there is a stretch of more than 3000 acres of flat, soft sleeches or slob land, a large part of which is covered at high tide by less than 6 feet of water. During neap tides a considerable portion of this mud is left entirely bare for several days. The intelligent visitor, passing the place at low tide, naturally asks, "Why is this vast expanse of mud not turned into good land by shutting out the shallow tide, as is done so advantageously in Holland?" This question is no new one, but has been asked repeatedly for more than two hundred years. We find, for example, in Sir Robert Sibbald's account of Linlithgowshire, written in 1710, the following passage at page 17 relating to the part of the slob land opposite the Kinneil estate between Bo'ness and the River Avon:

> "There is but a small distance betwixt the Mouths of the Water of *Carron* and *Avon*: and the Firth here is very Shallow

upon this South side for a long way, because of the vast quantity of Earth and Rubbish brought down there by Speats: the Shallowes have the name of the Ladies Scap, where there is a great variety of Shells of diverse sorts found, both *Marines* and *Fluviatiles*: The *Dutch* did offer some time ago to make all that *Scape*, good arable ground and Meadow, and to make Harbours and Towns there in convenient places, upon certain conditions which were not accepted: The *Dutch* have made many such Improvements in their own Countrey with their dykes: It is thought this might make the narrow part of the Firth deeper and the Navigation to the upper parts more commodious, if this design were prosecuted."

Since then some 800 acres have been reclaimed both on the north and south shores, and the work is still in progress on a small scale at Bo'ness, where the sea is being slowly pushed back by the deposit of rubbish along the beach.

This reclamation, as I shall afterwards show, has been of enormous advantage to the community of Bo'ness for industrial purposes; but the larger reclamations and schemes I shall now describe have been mainly intended to provide land for agricultural use, and their success must thus largely depend on the rent which the land will afterwards yield as an agricultural subject.

A portion of the Carse of Kinneil on the Duke of Hamilton's estate has been reclaimed long ago by a low dyke faced on the outside with stone. The land inside the bank is a few feet below the level of high water at spring tides, but this is a very old intake, the record of which I have not been able to discover.

There is, however, a complete account of the two reclamations on the Tulliallan estate at Kincardine, an epitome of which will now be given.

First Tulliallan Reclamation, 1821.—The first important foreshore reclamation on the Forth, of which there is a reliable record, was begun by Lord Keith, the then proprietor of Tulliallan estate, in 1821,

and is described by Mr. William Menzies, Lord Keith's factor, in Vol. XII. of the *Highland Society's Prize Essays*, published in 1839. In this very interesting paper Mr. Menzies gives an account of two reclamations, the first of which was carried out in the bay which existed in 1821 between Kincardine and Kennetpans. An embankment was begun in April of that year which enclosed an area of 152 acres, and had a length of 2020 yards. The spring tides rose to a height of 8 feet over the foreshore along the line of the bank. This bank was composed at first entirely of mud wheeled with barrows from each side. Subsequently some brushwood was added to strengthen it, and the average height was 11½ feet. It had afterwards to be faced on the outside with stone, and heightened 3 feet or more, as it subsided considerably during the course of construction. As the work progressed, the mud accumulated inside so as to raise the level of the enclosure and render the drainage more easy. For the first year, after the tide was shut out, the saltness of the ground prevented the growth of vegetation, and it was not till 1824 that drainage and agriculture were begun, and an attempt at cultivation was made. In 1827 the first good crop of grass was obtained, and the productiveness progressed till 1830, when the ground was broken up in rotation for oats, barley, potatoes, beans, wheat, and clover grass, which improved yearly as the salt was extracted from the ground, and subsequently yielded almost unequalled returns. The cost of this reclamation was between £6000 and £7000, and the rent was progressive as the land improved in fertility. Dividing this figure by 2020, the length in yards of the embankment, it will be seen that the cost of the latter was less than £3 10s. per lineal yard.

Second Tulliallan Reclamation, 1829.—The next reclamation of importance was carried out on the east side of Kincardine pier by means of embankment running to near Longannet Point, which enclosed an area of 214 imperial acres. This was begun in the spring of 1829, and progressed slowly so as to allow the mud to silt up inside. The spring tides rose 11½ feet over the line of the bank at

the Longannet end, and 7 feet at the Kincardine end. By the middle of the summer of 1836 the mud had risen over the lower parts of the enclosure to a height of 7 feet 9 inches, and had raised the surface above the high-water level of neap tides. Openings were left to allow the tide to enter and deposit its mud, and at last these were, although not without difficulty, closed successively, the sea being finally shut out in the end of February, 1838, nine years after the commencement of the work. The whole cost exceeded £12,000. Many difficulties had to be overcome, but the work was greatly aided by the facility for procuring stone from a neighbouring quarry, of which about 170,000 tons were used in the embankment. In this case the embankment, which was about 3000 yards long, cost at least £12,000, or £4 per lineal yard on the average. An additional expenditure was, however, caused afterwards by the necessity which arose for pitching the outer face of the sea wall with stone to prevent it from being damaged by storms.

The total area reclaimed was 366 acres, and the whole cost of the two operations was about £19,000, or, say, £52 per acre. At £2 agricultural rent (the value of the carse land at Kinneil for grazing at present), which is less than an acre of good land was worth half a century ago, a return of nearly 4 per cent. on the outlay is given, which is not high certainly, but more than many good securities yield nowadays.

Reclaimable Ground on South Side.—The wide expanse of sleeches or slob land between Bo'ness, Grangemouth, and Kincardine Ferry over 3500 acres in extent, offers a much larger field for enterprise of this sort; and from numerous plans and papers in my custody I shall now refer to the various schemes which have been proposed, and of what may still be done towards reclamation of that waste area, the extent of which is indicated on the accompanying map.

Mr. Livingstone Learmonth's Scheme, 1875.—In 1875 a bold proposal was made to reclaim practically the whole of the foreshore between Bo'ness and Kincardine Ferry, and take in an area of 3600

acres at one fell swoop. The proposer was Mr. Thomas Livingstone Learmonth, the enterprising proprietor of Parkhall estate in the vicinity, who had at his command a large fortune, which he, in partnership with his brother, meant to devote to this laudable purpose. The plans were prepared by Messrs. Blyth & Cunningham, C.E., and I am indebted to Mr. D. M. Westland of that firm, and to Mr. Learmonth's son, the present proprietor of Parkhall, for kindly supplying the information about the scheme which my late friend Mr. Livingstone Learmonth, who died 28th November, 1903, at the advanced age of eighty-five, was unable, owing to ill-health, to give me when I last spoke to him on the subject. The proposal was defeated in the House of Lords, owing, Mr. Learmonth once told me, principally to the opposition of Lord Zetland, whose family are riparian proprietors of land adjoining part of the ground included in the scheme. An embankment, at some places 22 feet high, was to be run round the foreshore from Bo'ness to Grangemouth along low-water line, and a new straight cut made for the mouth of the River Avon, with banks at each side to keep the tide at high water off the sleeches. A similar embankment was to be run from the mouth of the Carron at Grangemouth up the Firth to Kincardine Ferry, to take in the foreshore opposite the old Tulliallan reclamation. This proposal was estimated to cost £275,000, but the work could perhaps be done now at a lower price. At that estimate the land would have cost £76 per acre, which included a payment of £11 per acre proposed to be made to the riparian proprietors as compensation for any foreshore rights they might claim. Although agricultural land was much more valuable then than now, these charges were ruinously high, and almost enough to kill the whole project.

Foreshore Rights.—In this connection it may be mentioned that the foreshore rights of frontagers are often not very clearly defined. The Crown and the riparian proprietors sometimes both claim to have rights over the sleeches, and unless a proprietor or his predecessors have actually bought the *solum* of the foreshore from the Crown, and

so have acquired a special title, or have a Crown charter thereto, their actual rights to everything between high- and low-water mark must be considered as more or less shadowy. If the question were raised in Court, some of the claimants for compensation might find that, although they might have certain rights of *access* and *servitude*, they had much smaller *proprietary* rights to the *solum* of the ground than they supposed, and in demanding considerable payments from others who proposed to reclaim these foreshores, they were asking for something that did not properly belong to them. In such cases it is better for promoters of reclamations to bargain with the riparian proprietors to sell such rights as they might legally claim, and get the Crown to dispose of such rights as it might have, rather than incur the cost of subsequent litigation and obstruction. In this way they would obtain a clear title and disarm future opposition before beginning operations.

In this particular case the Duke of Hamilton, or rather Mr. Hy. Padwick, his Grace's commissioner at that time, was "morally" a promoter of the scheme, on conditions highly advantageous to the proprietor. Mr. Livingstone Learmonth was to pay him £1 per acre, or £1500, before he began operations, for the right to do so on the part of the foreshore *ex adverso* of the Duke's Kinneil estate. Twelve years were to be allowed for the execution of the work, and at the end of that time the Duke was to have the option (1) of either paying Mr. Learmonth the value of the 1500 acres of land so reclaimed, not on the basis of his expenditure in making the land, but on a valuation to be made by neutral arbiters, on a basis of forty-five years' purchase of the then agricultural value, or (2), if (as was most likely) he did not elect to do so (Kinneil estate being then exposed for sale), of giving up his rights to it on receiving £15,000 from Mr. Learmonth, or £10 more for every acre which the latter had reclaimed. Under this agreement Mr. Learmonth did not stand to gain much in any event, and the Duke, who took none of the risk, not even a share of the promotion expenses of the bill in Parliament, stood to make £15,000 at least for the foreshore rights to which he laid claim.

The other and smaller frontages were all to be compensated on the same liberal scale, but in spite of this there was still considerable local opposition. The total amount of compensation money at £11 per acre, which the scheme involved, was £39,600—far too large a sum to pay to people who would not take any share in the risk, and had only a doubtful claim for compensation after all. It was also far more than such a scheme could bear with any prospect of ultimate financial success.

Mr. Learmonth told me that, although annoyed at first, he was not sorry in the end that the bill had been rejected, since the scheme as estimated would never have repaid him. But at the same time it was undoubtedly a sad loss to the whole district. A splendid opportunity was missed of creating a new and useful source of employment and of carrying out a great public work, the benefits of which, had it been completed, must long ago have become abundantly evident. Mr. Learmonth, nothing daunted, went with his plans and ideas to Denmark, where more liberal terms were offered, and spent a sum of about £300,000 which should have gone towards enlarging Scotland, in reclaiming some 11,000 acres of a foreign country. This great intake, after a quarter of a century, considerably increased the size of the Danish kingdom but yielded the undertaker so little return for his enterprise that, as his son once told me, he would have sold the whole for £1 an acre if he could have found a purchaser.

Compensation to Frontagers.—Mr. A. Beazeley, M.Inst.C.E., in his excellent book on the *Reclamation of Land from Tidal Waters* (1900), devotes a chapter to the legal requirements and preliminary negotiations with riparian proprietors, the Crown, and others, that must first be settled before the details of any large reclamation scheme are complete. As to the amount of compensation to frontagers for foreshore rights, he states at page 264 that *one-tenth* of the land embanked has been mentioned, but according to Mr. Wiggins (a standard authority half a century ago) this is a larger deduction than almost any intake will allow so as to leave the adventurers

a sufficient chance of adequate remuneration for their enterprise. Mr. Wiggins arrives at the conclusion that *one-fifteenth* of the value of the ground reclaimed opposite any estate is a sufficient and fair proportion to allow the frontager as compensation. At this rate the riparian proprietors adjoining the unreclaimed slob land above Bo'ness would be amply compensated by one payment of £3 10s. per acre, on the assumption that the land when reclaimed was worth, say £52 10s. and yielded a rent of £2 per acre, or slightly more. Or else, in order to entirely remove the speculative element and at the same time to avoid a direct initial outlay by the undertakers and a cash payment on the basis of a more or less problematical valuation, the frontagers might receive *pro rata* a similar proportion of the land itself after it is actually completely reclaimed *ex adverso* of their respective holdings. It may be here mentioned that considerable parts of these foreshores belong to the Crown, and the riparian proprietors have no title to these areas. The Crown has, within the last half century, sold different pieces for reclamation purposes at prices varying from 7s. 6d. to £4 per acre, and these figures may be taken as an indication of the real value of unreclaimed slob land here.

Mr. Livingstone Learmonth's scheme was undoubtedly too ambitious, as the sea wall was to be carried out to the line of low water in order to gain as much land as possible, instead of being kept back, and placed where the foreshore level was not so low, and it could be built at much less expense. The effect of carrying it out so far would also have been to throw Bo'ness harbour into a deep bight that would probably have soon caused it to be completely silted up with mud.

Forth Conservancy Scheme, 1880.—Another proposal was drawn up in 1880 by Messrs. Thomas Meik & Son, C.E., in connection with a bill to constitute a Forth Conservancy. The foreshore to be reclaimed was bounded by an outer embankment that followed up a better line than Mr. Livingstone Learmonth's between Bo'ness and Grangemouth, and the acreage of foreshore to be enclosed was not

quite so large as that in Mr. Learmonth's scheme. I am indebted to Messrs. Meik & Son for information about their scheme, which, I understand, was to cost about £100,000 less than Mr. Learmonth's. The whole area to be reclaimed was 2925 acres, of which 2030 acres were below and 895 above Grangemouth.

The idea of a Forth Conservancy Board and a scheme of this sort was one to be commended in the interests of navigation, but the bill was dropped after the plans had been prepared, as there was a risk of opposition by shipowners and others on whom a small rate would require to be levied to pay interest on the works and redeem the capital outlay.

Bo'ness and Bridgeness Reclamations.—While the suggested large reclamation is still a work for the future, about 160 acres of the foreshore further to the east have been reclaimed since 1850 for industrial purposes on Kinneil and Grange estates, at Bo'ness and Bridgeness respectively with very great advantage to the local community. On Kinneil estate the reclamation has been effected by emptying down rubbish from the collieries and the now dismantled ironworks, where large quantities of blast furnace slag were produced between 1850 and 1880. On Grange estate to the east of Kinneil 86 acres of foreshore were acquired from the Crown in 1868 by the late Mr. Henry Cadell, the writer's father, *ex adverso* of the Barony lands of Grange, which did not originally include a title to the surface of the foreshore. The reclamation was proposed to be effected by "warping" or the accretion of mud by siltation inside a barrier of stakes and wattles to be run round the area near the line of low water. This scheme was, however, not carried out in my father's lifetime, and all the land he reclaimed was made by emptying colliery rubbish and slag along the beach as was being done at Kinneil.

After 1888, when the writer succeeded to the estate, he began the construction of a low embankment round some 30 acres of unreclaimed foreshore east of Bridgeness harbour to experiment on the warping process, and during the last twenty-four years he has continued the

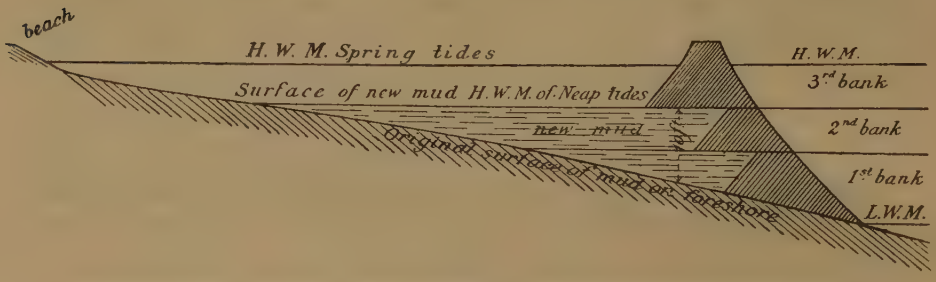
reclamation of the Grange foreshore, and has thus gained some useful experience besides having the satisfaction of adding a few acres to the size of Scotland, on which many honest folk can now make a decent livelihood where there was nothing but useless mud, sparsely inhabited by small crabs and sandworms, a quarter of a century ago.

The idea of a dyke of stakes and wattles did not commend itself to me, as there was available plenty of heavy rubbish from the colliery situated near low water at the east side of Bridgeness harbour, and with this the embankments were all constructed. At first a low bank, the top of which was only 3 to 4 feet above the level of the mud on the landward side, was run round the lower part of the foreshore when the tide was out. The bank was about 20 feet broad on the top, sufficiently wide for a double line of 3 feet light railway. It was not long before the calm water inside the enclosure became silted up with soft mud to the level of the rails on the bank. A second low embankment was run round the enclosure on the top of the first, so as to cause a higher stratum of water to lie calm behind it, and in time this too became smothered on the landward side under the rapidly accumulating silt. At the end of 1900, ten years from the date of the completion of the first bank, the mud had risen 10 feet over all the lower part of the enclosure, and the surface of the intake was well above the level of high water of neap tides and only submerged about 4 feet at ordinary springs.

The progress of siltation will be apparent by reference to the accompanying diagrammatic section across the original foreshore and embankments at Bridgeness.

The embankments were made of loose stones, ashes, and ballast, quite porous and open. At first the impounded water ran through the barrier as through a sieve, and no attempt was made to render it watertight. But the water that issued at low tide on the seaward side was always observed to be quite clear, the mud having been all filtered out as it percolated through the barrier. The filter, however, before long became clogged up, and the interstices of the bank were

entirely filled with plastic clay, so that it was converted into a kind of solid conglomerate as tight as a bottle. The ebbing tide no longer ran through it, but over the crest in a long thin cascade like the tidal waterfall at Connel Ferry on a very small scale.



Sketch showing Accumulation of Silt within Successive Embankments at Bridgeness.

After the enclosed mud had risen above high-water level of neap tides, the intake was surrounded by a third embankment about 6 feet high, which had to be made watertight to exclude the sea entirely. The sea was finally shut out in the beginning of 1901, about eleven years after the first embankment was begun. After the mud was dried up, it was partly sown down with grass. But here the agricultural part of the experiment suddenly ended. On the 28th October there was a great storm and an unusually high tide, and the sea burst through the bank at a weak place and flooded the whole enclosure. The gales lasted for about a fortnight, and on the 28th November the storm reached its height, when, it may be remembered, H.M. Revenue cutter "Active" was driven against Granton pier and totally wrecked, with a loss of twenty lives. The breach was not repaired for a long time, as the whole intake of some 30 acres was now so shallow that I found it could be raised above high tide level by the ordinary process of dumping down rubbish and ashes, large quantities of which could be got from the N.B. Railway Coy. for the emptying. A 6 or 8-ton truck can be emptied by an unskilled labourer for 1s., or at the rate of about 2d. a ton, and a good worker can at this

rate earn 5s. or 6s. a day quite easily. Almost the whole intake has now been thus filled up with railway ashes and colliery débris from the adjacent pits.

I have related these little circumstances, not because they are of any geographical importance, but because they are instructive as showing how to set about a much larger reclamation that would be of very great importance to the district.

It is to be noted that the ultimate use of the reclaimed land at Bridgeness is for industrial and not for agricultural purposes. The rich mud of the intake has been buried under 6 feet of stones and ashes, making a solum which is perfectly useless for agriculture unless covered with a foot of good soil. But here there was a local demand for land for woodyards and other purposes near the shore, and a good deal of the flat ground thus produced can be let at about £12 per acre for this purpose. The whole cost of an acre thus filled up is about £300, allowing nothing for the original value of the ground, and the gross return of £12 is thus only 4 per cent. on the outlay. The cost would have been larger if the sea had not assisted by the 10 feet of mud it brought in, but it took ten years to make this useful contribution. On places where there is no demand for ground for public works, and where agriculture is the sole industry, the mud would, of course, not be thus buried, but the area would require to be surrounded by a sufficiently strong bank to keep out the sea, which would for an hour or two at high tide be always a few feet above the level of the enclosure.

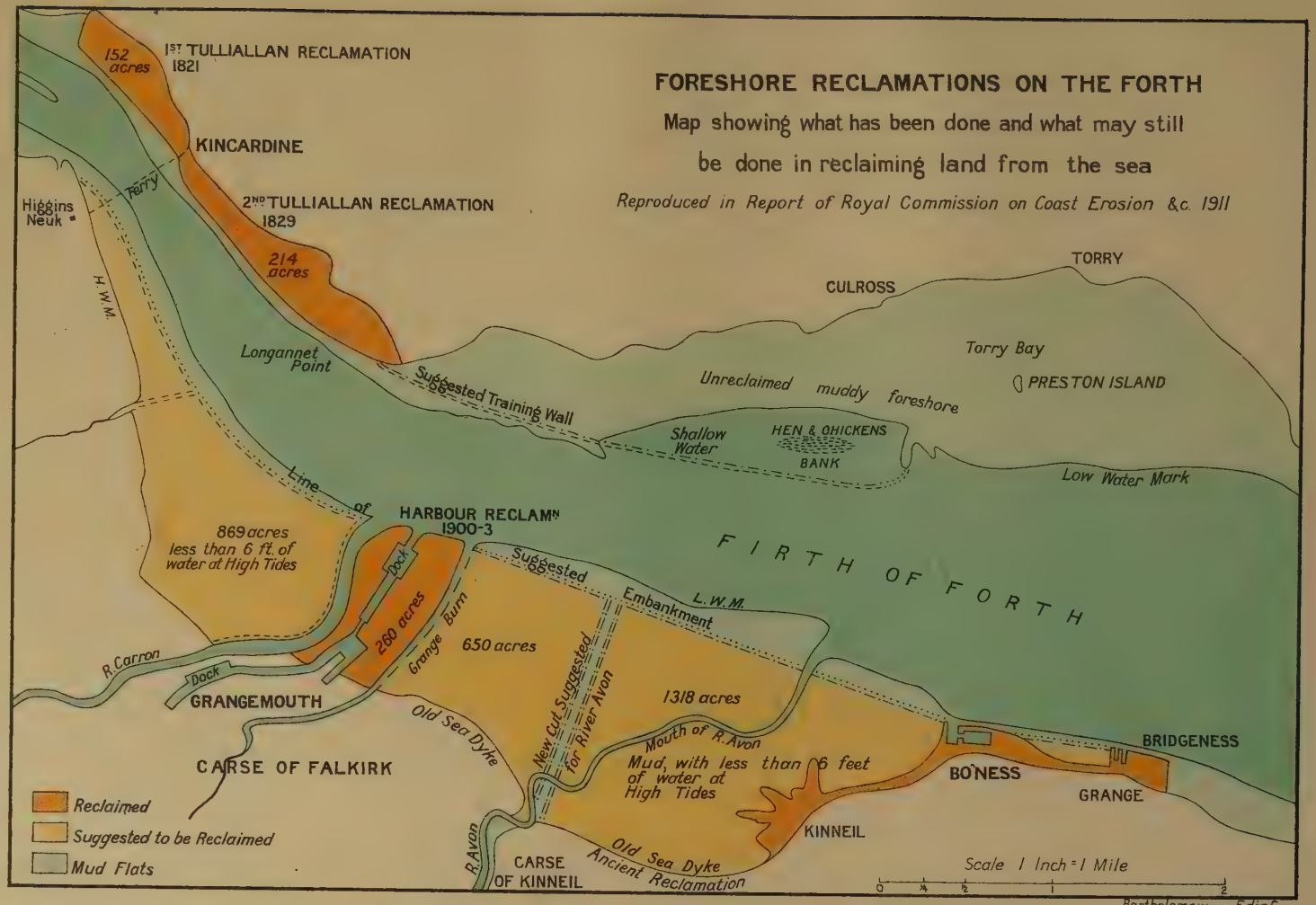
Two Kinds of Foreshore Reclamation.—There are thus two principal kinds of foreshore reclamations, (1) those meant for agriculture, and (2) the smaller class designed to produce land for harbours, railways, or riparian industries at places such as Bo'ness, where the adjacent ground is steep and the natural flat land along the coast is limited in extent. At some places the value of industrial land is so high that it will be profitable to expend far more than £300 an acre on reclamation works. From the point of view of employment of

the population, such works have proved of great advantage to Bo'ness and some other towns, although I am quite aware of the fact that enormous sums have been spent at Dundee and elsewhere in reclaiming land which is as yet quite unproductive, and cannot be let at all in the present state of industry. On the reclaimed land at Bo'ness and Bridgeness there are now, besides the dock belonging to the N.B. Railway Coy., which is the principal employer, and the collieries that were always on the ground, about sixteen smaller public works and woodyards, giving employment to some 1600 people, none of which were in existence fifty years ago. A great part of the recent industry of the town is thus directly attributable to the provision, even at considerable cost, of flat land close to the sea by the N.B. Railway Coy. and other local proprietors.

Industries such as I have referred to, other than agriculture, which after all is in the end the best and greatest—the staple branch of human occupation that preceded and will outlive all others—depend for their existence on many conditions and are subject to frequent changes and fluctuations in trade. The only perfectly safe use for land is to employ it for growing crops and raising live stock that will always be marketable while there are any inhabitants in the country.

Only a comparatively small area of the country is wanted for other purposes at special places, and in considering large schemes we are thus left to contemplate them from the point of view of the practical farmer in the first instance. There may, however, be important local conditions that contribute to the success of a scheme which might, perhaps, not be feasible from agricultural considerations alone. This point will be exemplified in the sequel.

Report of Royal Commission.—The writer was appointed to represent the County Council of Linlithgowshire and give evidence as to the reclamation of the foreshores *ex adverso* of the county, before the Royal Commission on 23rd March, 1909. There was a full discussion, and after more than 220 questions had been answered, and my proposals and plans had been laid before the


FORESHORE RECLAMATIONS ON THE FORTH
Map showing what has been done and what may still be done in reclaiming land from the sea
Reproduced in Report of Royal Commission on Coast Erosion &c. 1911
1st TULLIALLAN RECLAMATION 1821
152 acres
KINCARDINE
2nd TULLIALLAN RECLAMATION 1829
214 acres
Higgins Neuk
Ferry
H.W.M.
Longannet Point
Suggested Training Wall
TORRY
CULROSS
Torry Bay
PRESTON ISLAND
Unreclaimed muddy foreshore
Shallow Water
HEN & CHICKENS BANK
Low Water Mark
Line of
HARBOUR RECLAMN 1900-3
869 acres less than 6 ft. of water at High Tides
Dock
260 acres
Grange Burn
650 acres
Suggested
Embankment
L.W.M.
FIRTH OF FORTH
R. Carron
Dock
GRANGEMOUTH
Old Sea Dyke
New Cut Suggested for River Avon
1318 acres
Mouth of R. Avon
Mud, with less than 6 feet of water at High Tides
BRIDGENESS
BO'NESS
GRANGE
CARSE OF FALKIRK
KINNEIL
R. Avon
CARSE OF KINNEIL
Old Sea Dyke
Ancient Reclamation
Reclaimed
Suggested to be Reclaimed
Mud Flats
Scale 1 Inch = 1 Mile
0 ¼ ½ 1 2
Bartholomew, Edinr

Commission, it was decided to obtain further evidence from Mr. P. W. Meik, C.E., the engineer of the scheme of 1880, and to visit the locality in summer. The visit was made in due time, and the following is the part of the Report dealing with this evidence, which was published in June, 1911. The accompanying plan shows what has been already done and what may still be accomplished in the way of foreshore reclamation in this part of the estuary. This is a copy of the map referred to in the Report.

"33. *Firth of Forth.*—Evidence was laid before the Commission by Mr. H. M. Cadell and Mr. P. W. Meik with regard to a scheme involving the reclamation of 2000 acres of mud-lands between Bo'ness and Grangemouth. A map put in by Mr. Cadell, showing the reclaimed and reclaimable foreshores of the Firth above the Forth Bridge, has been reproduced as an appendix. The area proposed to be reclaimed is that which is considered to be the most suitable, though an additional area of 2000 acres might eventually be recovered.

"34. The schemes submitted by the two witnesses, while they relate to the reclamation of the same area, differ as regards the method of reclamation and the estimated cost. Mr. Cadell proposed that the reclamation should be carried out by the construction of a low training wall, behind which warp from the Firth might accumulate, to be supplemented by dredged material. When the accumulations behind the wall had reached a certain level, he suggested that an embankment at some distance inland should be constructed to cut off the tide from the warped area. He further proposed that the wall and embankment might be formed by the depositing of slag from the ironworks in the neighbourhood, such slag being now available at a very cheap cost. The reclaimed area would, he suggested, be suitable partly for agricultural and partly for industrial purposes, that part of the area nearest to the Firth being used for industrial purposes, the remaining portion further inland being devoted to agriculture. He gave a rough estimate of the cost,

amounting to £100,000, *i.e.* £50 per acre, which would include the purchase of the foreshore rights, now belonging to the Duke of Hamilton, and possibly to other frontagers, and also the cost of making a new cut for the River Avon. Mr. Cadell thought, however, that the area might be reclaimed at a cost of £40 per acre if the present channel of the Avon were embanked, a course which would not be so expensive as that of making a new cut, while it would probably prove as effectual. The area when reclaimed would lie in the midst of a large industrial district, and, according to Mr. Cadell, would lead, as in the case of previous reclamations carried out at Grangemouth and Bo'ness, to the establishment of shipbuilding and other industries, which must be of great benefit to the district. As regards the portion of the reclaimed area to be devoted to agricultural purposes, Mr. Cadell stated that agricultural land in the district commanded a rent of about £2 per acre per annum, and that as the reclaimed land would consist of rich alluvial deposit it would be very valuable, and probably fetch at least £40 per acre. Moreover, his scheme would be of benefit to the shipping industry, as he proposed that the work should be undertaken by a body of Conservators to be constituted for the Firth, who would be empowered to dredge the river in the interests of navigation, using the material for the purpose of reclamation, and to levy a due on the ships passing out of and in to the ports above the Forth Bridge as far as Alloa.

"35. Mr. Meik concurred with Mr. Cadell in advocating the creation, in connection with the reclamation, of a body of Conservators who would supervise the interests of navigation and those of the community in the Firth east of Alloa. He pointed out that all, or nearly all, the principal rivers and harbours in the country are under the charge of some public navigation authority, the Firth of Forth being practically the sole exception. The only public body which has any control in the interests of navigation in the Forth, the River Forth Commissioners, has no jurisdiction above[1] Alloa.

[1] This should read *below* Alloa.—H. M. C.

"36. Mr. Meik thought that any large scheme of reclamation such as he suggested could not be undertaken with a possibility of success as purely a commercial speculation; it must be bound up with the constitution of a public body such as the proposed Conservators, who would be enabled to undertake the proper dredging of the Firth in the interests of navigation. He said:

"'To carry out a large scheme of this kind you must energetically proceed with the works; you cannot go on from time to time as it suits, or else the interests of navigation will most certainly suffer. They must be laid down on a comprehensive scale and carried out systematically. That involves, even at the best, very considerable time, and the interest on the expenditure during the time will quite, I think, preclude any possibility of its being done to make it a commercial success.'

"37. Under Mr. Meik's scheme, the reclamation of the proposed area of 2000 acres would be completed within nine years of its commencement, and would involve the pumping by the proposed Conservators of about 2,000,000 cubic yards per annum of dredged material from the Firth on to the enclosed area. He stated that this process was necessary if the scheme were to be executed within a reasonable time. Mr. Cadell's plan of reclamation, he added, would take at least twenty years.

"38. With regard to the cost of the reclamation, which would be carried out by the construction of a long embankment, Mr. Meik estimated that during the first year the expenditure would be: Purchase of foreshore and frontage rights, £20,000; dredging plant, £60,000; works, £80,000; total, £160,000. During the second year the dredging of 2,000,000 cubic yards at 3d. a yard would cost £25,000; interest at 3 per cent. would amount to £5550; total, £190,550. In the third to the fifth years the dredging of 6,000,000 cubic yards at 3d. a yard would cost £75,000; total, £265,550. Mr. Meik did not add anything for interest after the second year because at the end of the first year's dredging he proposed that a

rate of 1d. per registered ton should be raised on all shipping entering the Firth above Queensferry, the present tonnage being about 1,900,000. He added :

"'Assuming this rate to yield £8000 per annum, it would cover the interest on capital at 3 per cent. with a surplus up to the end of the fifth year. At that period the land would all be reclaimed, and such of it as could be utilised for industrial purposes would be available for immediate occupation. Consequently the dredging operations could be curtailed to maintenance, and probably some of the plant sold. During the next four years the agricultural land would be prepared for cultivation and the river banks protected, the estimated cost being £40,000, making the total capital expenditure £305,550.'

"39. The value of the claimed area at the end of the ninth year Mr. Meik estimated as follows :

Agricultural land, 1500 acres at £60 per acre	£90,000
Industrial land, 500 acres at £300 per acre	150,000
	£240,000

The deficit of £65,550 would, Mr. Meik thought, be gradually redeemed by the surplus revenue from the shipping dues.

"40. It should be noticed that the schemes were submitted to Parliament in 1875 and 1880, by Mr. Livingstone Learmonth and Messrs. Meik respectively, for the reclamation of tidal lands in the vicinity of Grangemouth and Bo'ness, and abandoned in consequence of the opposition aroused. Mr. Learmonth's scheme was opposed by the frontagers and by expert engineers, who pointed out that there were grave objections to it, in that it would have the effect of placing Bo'ness in a bight where it would be subject to increased siltation, and, moreover, that it would lead to the abstraction of so much tidal water as to be prejudicial to the interests of navigation. This scheme involved the reclamation of 3600 acres. The scheme of Messrs. Meik, for the reclamation of nearly 3000 acres and the creation, as under the present proposal, of a Conservancy Authority with power to levy

a due on shipping, was opposed by the shipping industry and by the North British and Caledonian Railway Companies, who owned the ports of Bo'ness and Grangemouth respectively.

"41. It is not certain how far similar objections would be put forward to the present proposal: Mr. Meik contended that the Firth of Forth is not improving, and that arrangements will, in a short time, have to be made for its proper dredging in the interests of navigation, It is therefore possible that the shipping industry would not now offer the same opposition to the payment of dues as it did thirty years ago. To what extent the frontagers would advance objections remains uncertain.

"42. As regards engineering scruples, Mr. Meik admitted that his scheme would involve the abstraction of 25,000,000 cubic yards of water from the Firth, and that this loss could not be adequately balanced by any dredging of the channel. He pointed out, however, that such dredging would much improve the fairway. Although the estimates given by Mr. Meik as to the value of the land after reclamation were largely based upon supposition, he was clear that the site would be one of the finest in the country for shipbuilding purposes. Mr. Cadell and he concurred in the opinion that, as the proposed reclamation would lead to the improvement of navigation, the addition of a large area of land to the country, the employment of much labour, and the promotion of industrial activities, the scheme would, if carried out, be of great public benefit.

"43. In these circumstances we are of opinion that this matter of the possibility of the reclamation of land in the Firth of Forth is not to be lightly dismissed, and that it deserves further consideration and expert investigation."

CHAPTER XIII.

A NEW FORESHORE RECLAMATION SCHEME.

THE Commissioners, after hearing the evidence, concluded that the foreshore reclamation scheme described by the author was worthy of further consideration and expert investigation, and that was all I wished the Report to say. Such a proposal, far reaching in its effects on the development of the estuary, and involving many different interests, should not be adopted without sufficient information, discussion, and preliminary expert investigation. All this I freely admit, more particularly after perusing other parts of the Report, which show that in some estuaries reclamation works have proved injurious to the navigation and other interests, and at the same time have been unproductive from the agricultural point of view, involving immense and irretrievable financial loss to the undertakers.

But, while this is so, there are, I think, special conditions in the Forth estuary which make for success, and the objections that may be valid in connection with such works at other places have not so much weight here. If the principal criticisms can be satisfactorily met and the scheme shown to be feasible, its advantages, from most if not from all points of view, would be so great and numerous that a certain amount of risk in undertaking it would, I think, be perfectly justifiable. I have studied the matter for many years, and it appears to me that, although it was not found practicable a third of a century ago, circumstances have so changed that it is now more worthy of consideration than ever, and indeed the need and advantage of such

an undertaking is greater now than it has been in the past, while the difficulties in the way of the former schemes have greatly lessened with the lapse of time.

I shall now consider some of these difficulties, and afterwards I shall give an outline of a scheme that might possibly meet them and prove financially feasible.

Perhaps I may be considered too sanguine, but if there were among the human race no sanguine and enterprising individuals anxious to leave the world a little better in some way or other than they found it, and to see its people leading nobler and also happier lives,—if no such idealists emerged from time to time we should still be hungry and ferocious savages wallowing in the hopeless slough of primeval socialism. The Carron Company and the Scottish iron industry would not have been established nor the Blairdrummond Moss turned into a fruitful plain. The Scottish Mineral Oil Industry would not have been started nor the Forth Bridge built but for the advent of sanguine and clever men endowed with original ideas and the energy to carry them into execution.

Mr. P. W. Meik raised two important objections to the scheme, one of them physical and the other financial. If these are valid and not capable of removal or great mitigation, there is no need of discussing the matter any further. If the works are not only to be financially unprofitable but also injurious to the trade of the river, then they should, of course, not be attempted.

1. *The Physical Objection.*—The reclamation of 2000 acres, or any larger area of foreshore, would so diminish the size of the estuary that there would be too little tidal water admitted to scour out the channel properly at the ebb, and the estuary would become silted up in consequence.

In order to meet this weighty objection, I some years ago obtained from the Ordnance Survey Office figures showing the exact high and low-water area of the Firth of Forth between Queensferry and a point three quarters of a mile above Kincardine Ferry, where the sea and river

water join at low tide. The survey was made before the Grangemouth docks reclamation in 1900-3 had reduced the foreshore area by 260 acres, so that we must make this allowance in the following calculation :

			Acres.
The total area of the estuary at high water, after this reduction, is			20,834
Of which below low water		12,578	
Above low water on north side	3,231		
„ „ south „	5,025		
Total above low water		8,256	
Total as above			20,834

In calculating the quantity of water entering the estuary at ordinary spring tides we can arrive at a close enough approximation for present purposes, by taking the whole of the low water area over which the tide rises to the full height of 18 feet, and adding to this the quantity of water that spreads over the foreshores. The average depth of the water on the foreshores cannot be more than 9 feet or half of the full tide. Therefore we may simplify the sum by considering half of the whole foreshore as covered by the full depth of the water.

	Acres.
Total low-water area as above	12,578
One half of foreshore area 8256	4,128
Total area of water taken at 18 feet deep	16,706
	Cubic yards.
Each acre 6 yards deep contains	29,040
Therefore the quantity of water passing Queensferry at every spring tide is	16,706 × 29,040 = 484,434,240

Mr. Meik, in his evidence, said that the proposed reclamation of 2000 acres west of Grangemouth would have the effect of abstracting 25,000,000 cubic yards, but, if this be admitted, the proportion of 25 to 484 is only 1 to 19.36, or a very little more than 5 per cent. of the whole tidal flood. The quantity of water that would be abstracted is, no doubt, large absolutely, but not relatively to the whole volume of the tide, and a reduction of 5 per cent. of the scouring power would probably not be appreciably felt, so that this objection is not after all a very serious one.

In the forty-eight years between the dates of the Admiralty surveys of 1850 and 1898 the mud between the Carron River and Kinneil is shown on the charts to have silted up a foot or more over a large part of the foreshore, and since the construction of the Grangemouth Dock in 1900-3, it has risen still higher in the bay. The change can be clearly observed from the high ground to the east at half tide when the contour of the rising water shows that the more sheltered corners are being steadily silted up. The calculation makes no allowance for the tidal water abstracted by the Rosyth reclamations now in progress further down the estuary, but that will not seriously affect the scour. The accretions of mud just referred to, as well as the recent Grangemouth, Rosyth, and Bo'ness reclamations, have, no doubt, together diminished the tidal capacity of the estuary, but the whole remaining area is large, and the result does not seem to have made much difference in the scour of the main channel. This is, however, a point that cannot be accurately determined without a new Admiralty survey, or at least some soundings which would be necessary in connection with other investigations relative to the detailed consideration of the scheme.

In view of this objection, however, and of the smaller amount of siltation on the north shore, which is exposed to the full sweep of the prevailing south-west winds, I do not think it would be advisable to consider meanwhile any proposal to reclaim the broad foreshore of Torry Bay, which may otherwise seem a very good subject for such an intake.

2. *The Financial Objection.*—The next objection is the far more important one of the financier, and here there is room for much discussion and local investigation. Some years ago I made a calculation based on the cost of the Tulliallan embankments and my own small experiment at Bridgeness, and also on the assumption that materials could be procured and transported at a reasonable price from the local collieries, slag heaps, and other sources. The result was published as a paper in the *Transactions of the Royal Scottish Society of*

Arts,[1] and in the discussion that followed it I had the advantage of the able criticism of some experienced engineers, whose opinions were afterwards printed as an appendix to the paper. The scheme was to reclaim 2837 acres, of which 1968 lay between Bo'ness and Grangemouth and 869 to the west of the River Carron, very much the same area as was included in Messrs. Meik's scheme of 1880. My estimate worked out at £100,000, or £38 9s. per acre, and included an allowance to the frontagers of $\frac{1}{15}$th of the ground reclaimed, in name of compensation for foreshore rights. But it was pointed out (1) that the work would take many years to complete, involving considerable interest on the first capital outlay, and (2) that the outer bank would require to be faced with stone, as had been subsequently found necessary at Tulliallan, to prevent damage by the waves, both of which considerations would considerably add to the cost of the undertaking.

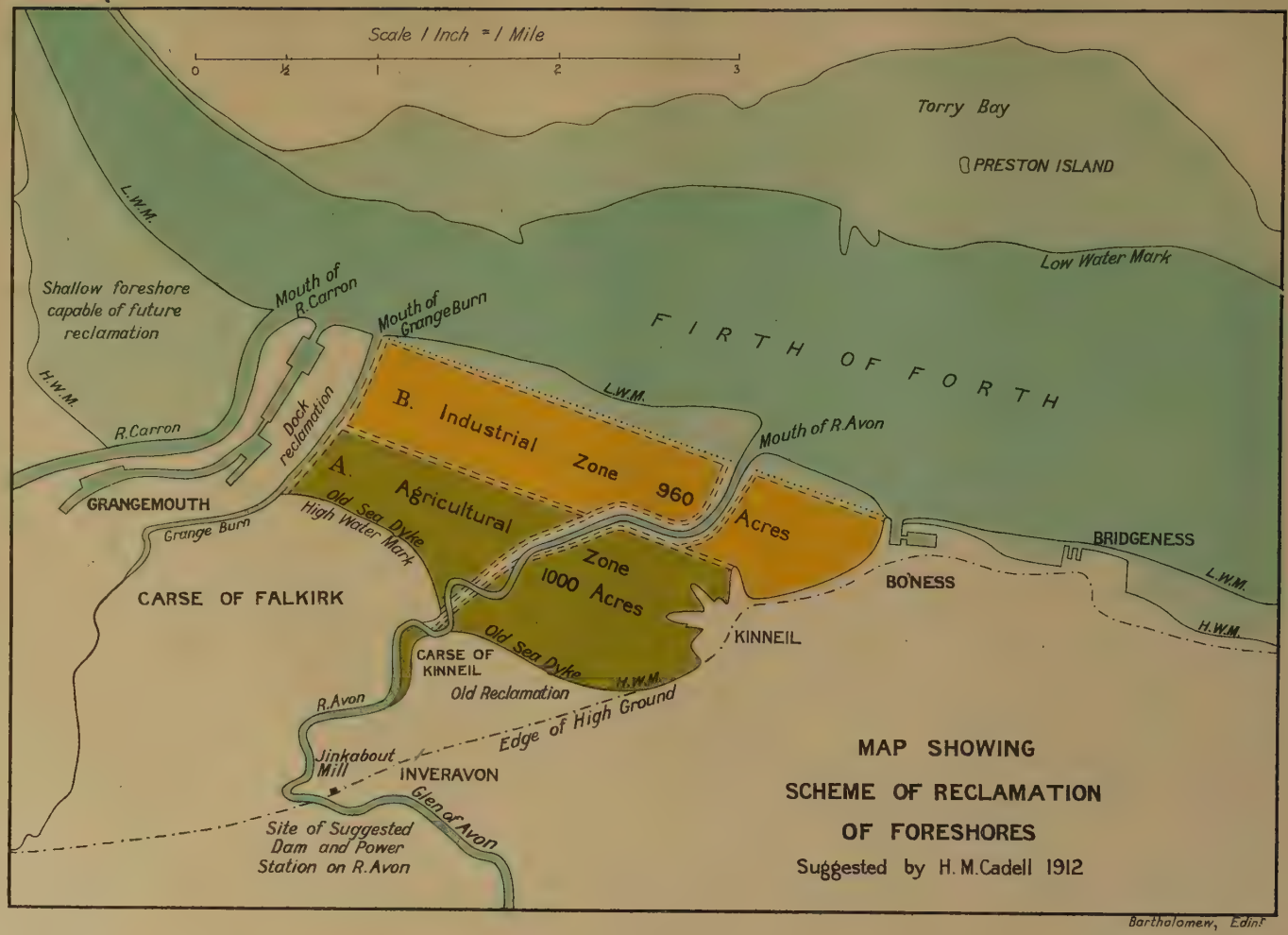
It was suggested by one of the critics that a more modest scheme would have a far better chance of success, and I am now inclined to agree with him, and to make an amended proposal that seems to meet most of the objections to the former projects.

Suggested Scheme for Reclamation of 1000 *Acres.*—Leaving out of consideration the very shallow foreshore above Grangemouth, which might be reclaimed afterwards if success attended the first scheme, the amended proposal that I would now make would be:

(1) To reclaim immediately the shallow part of the bay next the shore, which may be styled Reclamation A, extending only to about 1000 acres, and turn it into purely agricultural land without waiting for further accretion by warping. This scheme would stand on its own feet, and be independent of any river conservancy proposal such as Mr. Meik made in 1880.

(2) To reclaim later on, and by degrees, the outer part of the foreshore, about 960 acres in extent, in connection with a river con-

[1] Vol. XVI. 1903, pp. 13-32. The subject was also discussed in a paper by the writer on "The Industrial Development of the Forth Valley," *Scot. Geograph. Mag.* February, 1904.


Scale 1 Inch = 1 Mile
0
½
1
2
3
Torry Bay
PRESTON ISLAND
Low Water Mark
L.W.M.
Shallow foreshore capable of future reclamation
Mouth of R.Carron
Mouth of GrangeBurn
FIRTH OF FORTH
H.W.M.
R.Carron
Dock reclamation
B. Industrial Zone 960 Acres
L.W.M.
Mouth of R.Avon
A. Agricultural Zone 1000 Acres
GRANGEMOUTH
Old Sea Dyke
High Water Mark
Grange Burn
BRIDGENESS
BONESS
L.W.M.
H.W.M.
CARSE OF FALKIRK
KINNEIL
CARSE OF KINNEIL
Old Sea Dyke
H.W.M.
R.Avon
Old Reclamation
Edge of High Ground
Jinkabout Mill
INVERAVON
Glen of Avon
Site of Suggested Dam and Power Station on R.Avon
MAP SHOWING
SCHEME OF RECLAMATION
OF FORESHORES
Suggested by H. M. Cadell 1912
Bartholomew, Edinr

servancy, and to use this riparian land when reclaimed for industrial as well as agricultural purposes. This we shall call Reclamation B.

Reclamation A.—As to the first scheme, much depends on the cost of the materials. I have looked into this matter, and find that if the embankments can be laid down at 2s. a cubic yard or less, which is more than has been paid at some other places in the district, the plan is financially feasible. The high water is, as has been mentioned, not more than 6 feet deep over most of this area, but to be perfectly safe we shall assume 8 feet as the average height of spring tides, and add 4 feet to this to provide for abnormal storms and tides, making the average height of the sea dyke 12 feet. With a breadth on the top of 6 feet, an outer slope of 1 in 2, and an inner face with a slope of 1 in 1½, the cross section has an area of 36 square yards. The whole length of the necessary sea wall is 4000 yards.

4000 lineal yards × 36 gives - - - - - -	144,000 cubic yards.
At 2s. per cubic yard this would cost - - - - - -	£14,400
Stone pitching on outer face, 36,000 square yards, at 1s. - -	1,800
The sea dyke should thus cost not more than, say - - -	£16,200

This works out at a little over £4 per lineal yard, which is the same as the cost of the 3000-yard embankment of the second Tulliallan reclamation made entirely by hand labour, and considerably higher and much nearer low-tide level than this one. A large part of the bank could be made with solid mud lifted from the landward side of the foreshore by a grab dredger on a travelling crane with a long jib at a cost far below 2s. a yard, and not laboriously wheeled up in barrows by a regiment of labourers in the ancient style. But this is not all. The River Avon bisects the ground, and must be kept out by banks also, but these do not need to be faced with stone, and could be made of hard mud with grassed slopes. The Grange Burn also, which runs to the sea past the Grangemouth Dock embankment, must be prevented from flooding the intake. Embankments averaging 8 feet high and 4 feet wide on the top with 16 square yards in

sections would do for this, and the length required is about 5800 yards. The cost of these might be :

5800 × 16 = 92,800 cubic yards, at 2s.	£9,280
The total cost of the banks is thus :	
Outer sea dyke	£16,200
River embankments	9,280
	£25,480
To this must be added :	
Drainage of 1000 acres, at £4 per acre	4,000
Buildings for four farms of 240 acres each	8,000
Light bridge over Avon, say	320
Engineers' fees, 5 per cent. on cost	1,800
Farm roads, 4000 yards, at 10s. per yard	2,000
Compensation to frontagers, at £3 per acre	3,000
	£44,600

These are not fanciful figures, but are estimates based on what has been done at other places, and provided the compensation to frontagers was on the reasonable scale suggested, and there were no costly litigations or unforeseen calamities to the sea dykes, etc., I see no reason why the land could not be turned into a valuable agricultural estate for £45 per acre or less. It might safely be reckoned on to produce £2 5s. to £2 10s. of rent when the ground was once free of salt and in good heart, and this would ultimately give a gross return of 5 per cent., or a little more, on the outlay. Five per cent. would, no doubt, tempt very few investors, and besides this there has to be faced the burden of increasing taxation. This item, and especially the threatened new land taxation, is crushing the heart out of all territorial enterprise in the old country, and driving good capital and worthy people away to foreign shores, where they can work it in peace and to more advantage.

But, with such schemes in view, I have tried to get some State encouragement for patriotic enlargers of the empire at home to persevere in the good work, and my efforts have not, perhaps, been altogether fruitless.

A Select Committee was appointed by Parliament in 1906 to take evidence from various sources on the proposed Bill for the Taxation of Land Values. The writer appeared and gave evidence about various matters, including the cost and the great public advantage of such works, and the Chairman of the Committee, the Right Hon. Alex. Ure, K.C., M.P. for the county, afterwards inspected the reclamations at Bridgeness under my guidance, and expressed himself as much impressed with the advantage of the work to the community. The report which was published in December, 1906, gave effect to my suggestions that such lands might be exempted from taxation for, say, the first twenty years, so as to give the undertakers some encouragement in their enterprise. The following paragraph contains the Committee's opinions, which it may be hoped will be acted on if and when Parliament finally deals with the subject:[1]

"But, further, it has been brought under the notice of your Committee that in some instances exceptional and substantial expenditure has been incurred in preparing a site for building. As it originally stood, the site was, on account of unevenness of surface, slope, or it may be the character of the soil, unfit for building operations. But judicious expenditure has rendered it suitable. In such a case, if the owner can satisfactorily prove the amount of the expenditure, your Committee consider that allowance ought to be made for it at all events, if it has been incurred within, say, twenty years of the date of the valuation. To make such an allowance would, in the opinion of your Committee, be in strict conformity with the principles of the Bill, which aims at relieving all owners of rating based on industrial expenditure. *These observations apply with exceptional force to land which has been reclaimed from the sea.*" (The italics are mine.)

There is, however, no certainty that Government will give any more encouragement to owners of reclaimed land than to landowners of any other kind, as they are all apparently regarded as public

[1] *Special Report*, page xxvi. par. 15.

enemies at present. It is hardly to be expected that the land so made will be freed from taxation of every kind, as the inhabitants should have plenty of healthy children who will require education, and the school rate should certainly be paid by them. But there should be no paupers, and thus the poor rate might well be dispensed with. Farmers' profits, it may be mentioned, are reckoned at one-third of their rent, and as all incomes of £160 or under are free of income tax, no tax under Schedule D is payable by farmers whose rentals do not exceed £480. The proposed farmers, if they occupied holdings of 240 acres or less and paid rents of £2 per acre, would thus be free of income tax even if they made a profit of £1000 a year, and from this point of view it would thus be best to have only comparatively small farm holdings laid out on the new land.

But this brings us to another aspect of the question. There are various indications that the days of agricultural depression in this country are passing away, and that better times are in store for the cultivator of the soil. The enormous increase in the population of America and Canada is having the effect which has been foreseen every year in recent times with increasing clearness. The vast population growing up across the Atlantic is beginning to require all the food which can be produced at home for its own consumption, and the surplus for export from that quarter will no doubt diminish steadily. Prices of food either in the shape of cattle or cereals will therefore certainly sooner or later rise considerably in this country, and *it will become not only advisable but a matter of urgent necessity* for us to grow as much grain and potatoes, and breed and feed as much live stock at home as the land can possibly produce. Even now the rise in beef is beginning. I was myself a farmer for twenty years, and 35s. a live hundredweight was considered fifteen years ago a very good price for fat cattle, but now 40s. to 50s., or even 55s., is what feeders have lately been getting for good fat stock. Rearing fat pigs has also been a most profitable industry during the last few years when pork has been high in price. I have seen wheat selling

for only 20s. a quarter when it was more profitable to feed pigs with it, and so turn it into pork and hams rather than sell it to be made into bread directly ; but now it is selling at from 35s. to 40s., and in 1911 barley was almost as high as wheat. This rise in prices will apparently probably be more or less permanent.

The result will be that the value of good land will go up, and reclamation schemes will again become practicable, as there will be some prospect of a fair return, which there has not been for a whole generation, unless, of course, the State interferes and bleeds such enterprise to death. The scheme outlined for the reclamation of the foreshore will thus become more than feasible if the rent of the land rises to £3 or £4 an acre, such as land of this quality used to fetch here when farmers were thriving half a century ago, and still does in some parts of Midlothian. It will thus pay well to spend £45 or £50 an acre, or more, if the land is to yield such a good return. There is a great demand for small farms of 100 to 300 acres in good parts of West Lothian, and whenever a good farm is advertised to let, there are perhaps a score of applicants for it. When I gave up my own home farm of 200 acres in the vicinity a few years ago, there were twenty-five applicants, several of whom offered more than £2 per acre of rent for it, and since then the prospects of agriculture have continued to improve in the district.

Such heavy, stiff land, however, requires skill and knowledge to work profitably, and is not well suited for small holdings. It is best fitted for wheat, beans, and grazing, and cattle have been found to thrive uncommonly well on land such as this, with a little salt in it. Besides this the number of buildings that would be required for small holdings would make the price too high, unless the rent were sufficient, and the small holders had outside jobs to work at during their spare time. There might, however, be a part of it allocated in this way near the towns where other work is obtainable.

The drainage of such low ground is an important and difficult matter, but the water power of the River Avon might be turned to

advantage here. By means of a turbine above Jinkabout Mill, near the place marked on the map, where there is sufficient fall, electric energy could be cheaply produced and conveyed to motor pumps at different parts of the intake.

Of course, such a scheme would be best carried out by the riparian proprietors themselves, if they would conjointly undertake it. The Duke of Hamilton is the largest of these, and has on his estate the necessary materials for the embankments and other works. But I am only anxious to see the Forth Basin more developed, and, so long as the work is done by some one, it is immaterial to me who that some one may be. I should like this book to contribute in some way to the improvement of the district and the betterment of its people, and this is why I have devoted so much space to the subject. It is not so much knowing what to do as knowing how to do it that is wanted, and for want of the knowledge and the spirit of enterprise this waste area has lain idle for 200 years, when it might have been, like Blairdrummond Moss, turned long ago into a fruitful garden, giving employment to a thriving rural population. If the local proprietors are still unable or unwilling to carry out such an admirable piece of work, the scheme is, I have endeavoured to show, feasible for an entire outsider or even for a State-aided public body, provided the necessary facilities are given and no senseless opposition is shown, such as destroyed all chances of success of the schemes of last generation.

Reclamation B.—The second part of the scheme might or might not be adopted at once, as it is quite a separate undertaking, involving the reclamation of about 960 acres of deeper foreshore. This could not be at once turned into useful land, but would require to be filled up several feet, either by natural warping or by the deposit of dredgings, or by both processes combined. There are, however, here also several favouring circumstances to be considered.

(1) In the natural course of events Rosyth Dockyard is likely to improve the industrial status of the estuary. It may become an

attraction to other maritime businesses, and shipbuilding, ship repairing, rope making, or the breaking up of old vessels—a local industry already established at Bridgeness—may develop to large dimensions in other parts of the estuary. For such industries a better place could not be found than the flat land which would be created near low water mark beyond the purely agricultural zone of Reclamation A.

(2) Again, it is quite possible that coal, and perhaps ironstone also, will be found at a workable depth in this area, and by-and-bye, as other neighbouring coalfields approach exhaustion—of which there are already signs—it may be profitable to open up a large colliery with deep shafts in the suggested industrial zone of the reclamation. This cannot be done without first making a road for access to the coalfield, and providing the facilities for making up land round the pits. But a colliery at that place would have many natural advantages, a list of which I need not give here, as they will immediately occur to the mind of any practical coalmaster who knows his business. Such a tenant would be able not only to pay a substantial rent for the surface of the ground, but would also contribute a great deal of useful rock débris for the embankments.

(3) An immense quantity of mud is being dredged from Bo'ness and Grangemouth Harbours every year, and dredging may be required at Rosyth in future years. The Caledonian Railway Coy., the owner of Grangemouth Docks, spend about £4500 in clearing the mouth of the harbour of mud which accumulates to the extent of 200,000 cubic yards every year. The N.B. Railway Coy. spends £6000 a year on similar work at Bo'ness. These are the official figures recently obtained from the general manager of each company, and the expense is not diminishing. The mud is put into hopper barges and conveyed down the Firth to be deposited in deep water near the Bridge. A considerable part of the cost of dredging consists in taking away the dredgings 10 or 15 miles, as the case may be. If a suitable receptacle were thus provided close to each harbour that

would hold the dredgings and not allow them to be washed back again, a great deal of needless expense would not only be saved, but much useful land might incidentally be produced.

(4) Further than this, a great deal of the suspended silt in the water which settles in the harbours might be intercepted and made to settle in a place where it would do good instead of harm. The water might thus be clarified considerably, and there would in time be less mud left to settle. The mud does not nearly all come down the river directly, but is, to a large extent, derived from the flogging of the foreshores by the waves in stormy weather. This can be proved by going out in a boat, when the brown muddy fringe is found to hug each shore, and the water in the middle of the Firth is seen to be comparatively clear. Were all the mud directly brought down from Stirling by the river, the estuary should be as turbid in the centre as at the sides. By enclosing the slob lands a great part of the suspended mud would be thus intercepted at the source, and only the small quantity transported by the river would remain to be dealt with, so that the cost of dredging would probably be much reduced.

(5) The channel above Bo'ness is very shallow, and as it is desirable to improve it so that larger vessels can pass up to Alloa and Grangemouth at low tide, the river would be much the better of embankments at each side near low-water mark. These would take the form at first of low banks of rubble or "training walls," to direct the current and make it scour out a proper course instead of spreading out over a wide expanse of foreshore, where its velocity is greatly diminished.

(6) If the proposed Ship Canal for large vessels is ever made across Scotland, this end of it will require the estuary to be deepened and freed from mud as far as possible if the canal is to be of any use at all, and further, such an enclosure as this would be an admirable place to deposit the soil from the excavation. Indeed, it would not be nearly large enough for the purpose.

For these and other reasons it would be highly advantageous both to the navigation and the development of local industry to carry out a scheme of reclamation of the outer half of the foreshore in connection with a Forth Conservancy such as Messrs. Meik proposed in 1880.

I have made enquiry from the various Customs officers at Bo'ness, Grangemouth, and Alloa, as to the total registered tonnage of vessels inward and outward bound to and from these ports, and this, it appears, is altogether about 400,000 tons yearly. Now, if for the sake of improving the fairway by dredging, training walls, or embankments, a due of say 5s. per 100 registered tons were to be levied, the total amount of revenue from this source would be £10,000 a year. As the actual tonnage is more than double the registered figure, the proposed due would not amount to more than about a farthing a ton of cargo, which should not arouse much opposition from the traders, whose co-operation, along with that of the railway companies, it would, of course, be necessary to secure. The dredging of the two harbours already costs more than this, as we have seen, and if a Forth Conservancy were to save a good deal of their outlay the railway companies would be the gainers, and could afford to pass on some of the benefit to their customers. They would, no doubt, be substantial gainers in sundry other respects as well.

To begin the scheme, my proposal would be to run a low bank of rubble all the way from Bo'ness to Grangemouth, as was done at Bridgeness, and let the mud silt up behind it to a height of 6 feet or so. This would form a training wall to direct the main current of the river. At each end the bank might be made up to high-tide level with branches or groynes projecting shorewards at right angles, so as to form enclosures which would be adjacent to the respective harbours at first. The harbour dredgings might be all discharged into these basins, and as they became thus filled up to the level of spring tides the area of land so reclaimed would be gradually extended along low-water line and made available for industrial purposes at

each end of the reclamation. This would obviate the expense of taking the dredgings down to Queensferry, and be perfectly effective in preventing the possibility of some of the dredged mud being washed back at flood tide. A low training wall might be also made on the north side of the estuary from Longannat Point to the Hen and Chickens Bank, and the current thus directed would naturally tend to scour out an even channel to the advantage of the navigation. The fairway of the main channel, under a Conservancy scheme, would also have to be dredged, and these dredgings would likewise contribute to the filling up of the enclosure.

Such land would, of course, take several years to make, and would be much more costly than that of the agricultural zone; but should the south bank of the Forth ever become a very busy place with new collieries, shipyards, and other works, the rental of the ground will correspondingly increase, and it will in the end become quite profitable to spend £200 or £300 an acre, or even more, on the reclamation.

If this idea is ever carried out, the inhabitants, other than farmers, should, as far as possible, be provided with houses on the higher ground overlooking the Carse, where there are beautiful and more healthy sites for dwellings and garden cities, and they could be conveyed to and from their work by electric or oil motor cars on light tramways a mile or two in length.

It will be observed from the maps that the River Avon issues from a glen in the high ground overlooking the Carse at Inveravon, 2½ miles west of Kinneil. So flat is the Carse land that the effect of the highest tides of the equinoctial springs is felt in the river as far up as this point. Above Inveravon, however, there is a sufficient fall to provide power for the adjacent meal mill at Jinkabout, and by making a larger dam across the narrow glen the available water power might be conserved and greatly augmented.

If such a scheme of reclamation as I have suggested were to be

carried out and developed on a comprehensive scale, the Avon might very well be harnessed, and made to provide a supply of cheap electrical energy for pumping, threshing, or lighting purposes on the new territory. The volume of water is not very large, it is true, but is greatest in winter when pumping and lighting would be most needed to keep the fenland dry and cheery.

A Look ahead.—That is, however, looking many years ahead, and subject to so many important "ifs" that it is not possible to venture on any probable estimate of the whole cost of this part of the scheme. But, after all, an estimate to reclaim, say 1000 acres at £50, and another 900 at say £250, amounting in all to £275,000—the sum Mr. Livingstone Learmonth intended to spend—is less than quarter of the price of a single battle-ship that after sixteen years will be thrown on the scrap heap. It is also less than half the sum that has been lately spent by the Government on the salaries of hundreds of unproductive and more or less useless officials vainly trying to arrive at the hypothetical value of the land in the United Kingdom, which valuation will certainly never make the land in any way more valuable than it is at any particular moment, or give any more employment to people who produce the food and wealth which keeps the community in existence.

The present scheme, on the other hand, offers a tangible and permanent monetary return on the outlay. This may be greater or smaller according to circumstances, but will never in any case be absolutely nil, and the land so created, instead of deteriorating like a Dreadnought, will improve like good wine as years go by, and, like the Blairdrummond estate, will afford an honest and steady livelihood to a large rural population where there is not a living soul just now. If the wheat grown abroad is soon to be all wanted for local use, we shall have to be more independent in the future than we have been for a generation, and every acre of the home land that can be brought into cultivation will, before many decades are past, have to be turned to the best account. The sooner, therefore, we

start to seriously and practically consider the problem, the better for ourselves and our children after us.

It is also important in this connection to consider the promotion of industry other than agriculture. Of late years a paternal and well-meaning Government has passed many Acts of Parliament ostensibly in the interests of labour. Most of these are in one respect at least very much against the interests of labour, in so far as they have the effect of making it increasingly difficult to carry on industry in this country and provide employment with much prospect of an adequate return to the employers. Old-age pensions, compensation for injuries, insurance against sickness, regulation of time and wages, prevention of accidents, as well as the defence of the country, are, no doubt, admirable things in their way, but none of them are directly productive of wealth. Indeed, they are all more or less expensive luxuries that must be paid for. The result of much of this legislation is to injure industry by excessive taxation and interference, to discourage new enterprise, and to drive away capital and, in consequence also, the best workmen from the country. The emigrants, many of whom have come to me for certificates of character before sailing, are not agricultural labourers alone, but miners, masons, joiners, and plumbers, and especially men in various branches of the building trade which has almost been brought to a standstill since the natural effect of this kind of legislation has begun to be felt.

My proposition is, therefore, that it is now high time for the State to take a little broader view of the whole situation than it has hitherto done, and do something for the improvement of the land and the promotion of profitable industry on it, and thus help to make the country, whose inhabitants need so much protection, more worth the protecting itself.

Colliery and other kinds of accidents are, no doubt, calamities which all good men deplore, and all reasonable precautions should be taken to prevent them. There is one certain cure that will

absolutely prevent the loss of life in mines and the payment of too small wages to miners, and that is, to shut them all up and prevent any dangerous new pits from ever being sunk in future. The tendency of legislation is all in that direction just now, and it is high time for statesmen to look at the question from the other side, and endeavour by such means, among others, as I am now suggesting, to keep our people at home and promote useful and, at the same time, profitable employment, particularly in rural districts such as this and other improvable localities.

A large number of labourers are being employed at the Rosyth Dockyard a few miles away, which is, perhaps, a necessary but not a directly productive piece of construction. In a few years the work will be completed, and hundreds will be discharged. If the reclamation scheme I have outlined were ready for execution by that time, many of these men and a great deal of otherwise idle contractor's plant might be advantageously employed on a national improvement which would prove not only a continual source of employment for all time, but a revenue-producing subject that would by-and-bye help to repay many expensive national schemes, including that of the Naval Base itself!

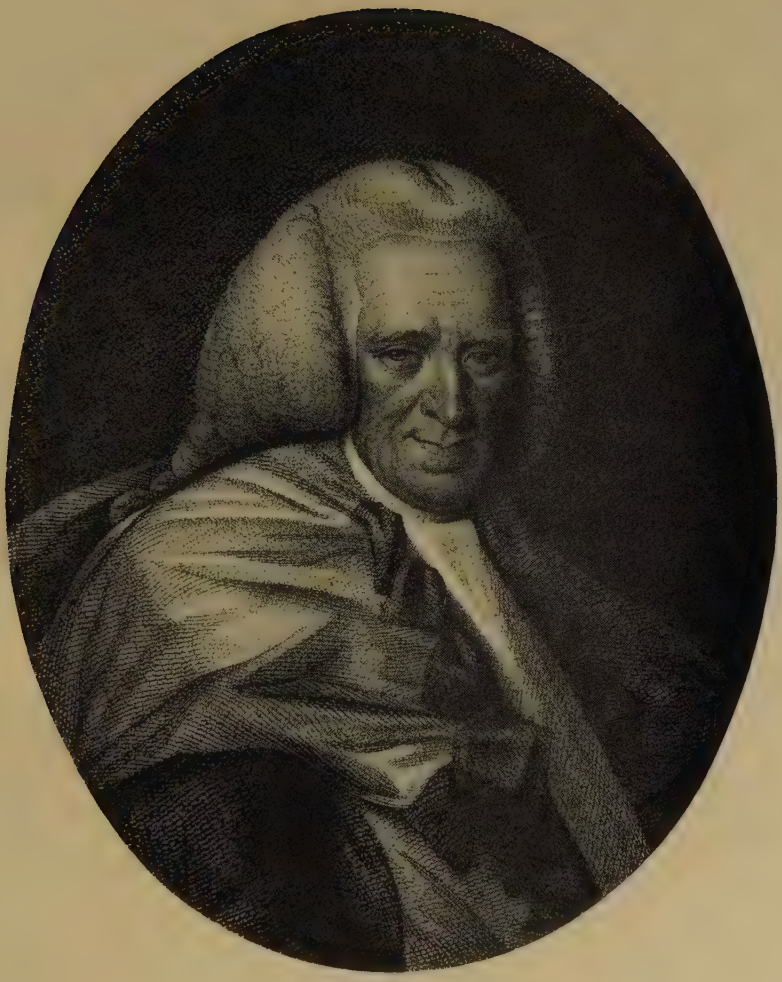
CHAPTER XIV.

THE CLEARING OF BLAIRDRUMMOND MOSS.

A FAMOUS OLD LABOUR COLONY.

In the latter half of the eighteenth century, when the national awakening of Scotland was just beginning, and men of brains and enterprise were everywhere turning their minds to the better development of the country, a remarkable experiment was begun by a remarkable man on his domain in the Vale of Menteith, the name given to the upper part of the Forth Valley. Seven years after the Carron Ironworks were established, Henry Home, Lord Kames, a distinguished judge, critic, and author, directed his acute and versatile mind to the very practical scheme of turning a barren moor into a fertile plain, and covering land which was once an uninhabitable quaking bog with scores of happy families. In 1766 Lord Kames, who had been improving his land in another district, succeeded through his wife to the estate of Blairdrummond, near Doune in Perthshire, part of which included the Carse land above the confluence of the Forth and Teith.

At that time most of the Carse land between Stirling and the Menteith Hills was covered by a dreary expanse of peat moss and heather which stretched for some twelve miles up the valley, and formed with its deep and treacherous pools an almost impassable morass from one to two miles broad. Known at different places as the Flanders, Cardross, Kincardine in Menteith or Blairdrummond



LORD KAMES.

From Millar's *Scottish Prose*, published by James MacLehose & Sons, 1912, p. 192.

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Moss, it lay to a depth of from 6 to 12 feet over a plain of good alluvial land, the surface of which was about 30 feet above the level of high tides. The underlying ground consisted of fine gray clay with beds of shells, but no stones of any size. He considered it a highly desirable matter to remove the peat and lay bare the good land below, but how to sweep off the barren covering and reclaim much of the ground on sound economic principles had not yet been discovered.

Lord Kames, although in his seventieth year, had a young heart and a strong mind in an equally vigorous body, and at once set himself to tackle the problem. His plan required many years to complete, but he courageously set to work, and although he did not live to see the end of it, he laid a good foundation, and worked at it for the remaining sixteen years of his useful life. He died in 1782 at the advanced age of eighty-six, and his son and successor, George Home Drummond, carried on the work with even greater skill and energy, and introduced several important improvements, which largely conduced to the final and complete success of the old judge's great project.

Various accounts have been published of what was described by Sir John Sinclair as "the most singular and considerable improvement that has yet been executed in any parish in Scotland. The *Old Statistical Account*, in the Appendix to Vol. XXI., gives the best description of the progress of the work up to nearly the end of the eighteenth century. There is a further description in the *Farmer's Magazine* for 1817, with a plan showing the progress of the operations up till 1813, and the *New Statistical Account of the Parish of Kincardine in Perthshire*, published in 1844, devotes a few pages to the same subject. Mainly from these papers, and from the information kindly given by Mr. David Ballingall, the factor of Blairdrummond estate, when the writer recently visited the district, the following authentic account has been drawn up of an episode which, although now almost forgotten, is full of human as well as of economic interest

and deserves to be recalled for the information and instruction of the present generation.

The writer in the *Old Statistical Account* of 1799 says: "There is probably no track of land of the same extent, equally unprofitable and useless, that has ever been rendered so productive and populous in any part of the three kingdoms. As there are extensive tracts of waste land similar to the Moss of Kincardine, both in Britain and Ireland, the successful improvement here described well deserves to be generally known and pursued. Whatever advantage accrues from it to the proprietor is meritoriously obtained, as by this practice the produce of the country in corn and cattle is enlarged; the country itself is rendered more populous, and the lowest of the people not only find beneficial employment, but it affords motives to excite them to the exertion of the most vigorous and useful industry."

These words are well worth recalling now at the end of 113 years, when there is still the need of making the country districts more populous and promoting rural industry. In 1766, when the work began, Scotland was poor and discontented. Only twenty years previous to this the Jacobites had been finally quelled and the Highland clan system had been broken up. Many of the poor clansmen, to make room for sheep, were being driven from their native glens to found new colonies in America, or to settle wherever they could find some employment in the Lowlands, and it was the reclamation of the Blairdrummond Moss which gave hundreds of them the very kind of useful occupation that they required at home, and the very sort of work that strong and hardy men alone could carry out.

About 1500 Scots, or 1800 imperial, acres of Blairdrummond estate lay under the moss, but this was only a part of the whole moor, which was more than 10,000 acres in extent. Even yet the western part of it, known as the Flanders Moss, which occupies the centre of the valley near Thornhill, and the Cardross Moss, near the Lake of Menteith, is still largely unreclaimed, so that anyone who may wish

to follow in the footsteps of Lord Kames can find a field for his enterprise in the same locality.

Before 1766 a few hundreds of acres had been cleared of peat round the edges where it was only 3 or 4 feet deep, but these attempts at reclamation had not proved very successful, and Lord Kames made up his mind that the only effectual way of laying bare the underlying clay was to use water-power and sweep off the whole moss into the Forth. The land being perfectly flat, the operation was far more difficult than if there had been any slope down which the peat might have been made to travel.

He began by trying to find out how much it cost to remove the moss on day's wages or by contract, but this soon proved that he would have to spend £12 to £15 an acre, and that the whole work of reclaiming 1350 acres would cost him some £20,000, which was out of the question in those days, and would entail the constant personal superintendence which he could not afford to give.

Another plan had to be tried if the work was to be successful, and the method finally adopted was to lease the moss in sections to small holders, who received a little financial help at first, but paid no rent until the return from the reclaimed land had indemnified them for their work in clearing their respective plots.

A channel was first cut down through the moss from north to south into the clay below. At the north end a stream of water that had been used to drive a mill was diverted into it, and was thus led for a distance of about a mile to the Forth at a gradient of 1 foot in 100 yards. The water was found capable of carrying off as much peat as twenty men stationed 100 yards apart could throw into it. The moist clay was as slippery as soap, so that the thick stream was well lubricated as it moved slowly down to the river.

The next thing was to find the people to do the work, and here there was at first some difficulty. The area was marked off into lots of 8 Scots (or about 10 imperial) acres, long and narrow in shape, and running at right angles to the channel. In 1767 one tenant

agreed to take a lease on the prescribed terms. These were: a tack of thirty-eight years, with no rent for the first seven years. The landlord provided the tenant with timber to build a house, and 2 bolls (or 8 bushels) of meal to live on while he was building it. At the eighth year rent was to begin at 1 Merk Scots (or 1 3⅓d.), and increase by a merk every year till the end of the nineteenth year, and during the last five years, when the tenant should have begun to keep poultry, a hen was to be added to the annual cash payment. At the beginning of the second nineteen years he was to pay a rent of 12s. for each acre cleared and 2s. 6d. for each acre not cleared, plus two hens yearly. This was a low rent, no doubt, for such good soil, but the tenant was entitled to a liberal reward for his exertions, and although few were at first found willing to undertake the risk, as soon as its advantages came to be found out plenty of settlers came flocking to the new labour colony.

A second tenant was settled in 1768, but like the first he was not a mere unskilled labourer, but a tradesman with another occupation to fall back upon when not employed on his croft. The prospect of an independent holding, however small, with fixity of tenure for a long period, no doubt induced these settlers to break the ice at first, and, as there was always plenty of peat fuel for the digging, the winter's hearth was sure to be warm and cheery. Their work was afterwards further encouraged by the gift of numerous prizes in the shape of ploughs, harrows, spades, and clover seed, for the removal of the greatest quantity of peat in one year, and large numbers of these useful things were thus distributed, to the great advantage of the settlement and its poor inhabitants. But the settlement was slow at first, and in 1769 only five more buildings were taken up. These "moss lairds," as they were called in derision, were at first a topic of ridicule in the district, and the scheme was regarded as that of an unpractical visionary, destined to early failure. The neighbouring farmers put every obstruction in the way, and it was feared that the hungry Highland settlers would ultimately prove

undesirable aliens and end by becoming a burden on the parish, so that their reception by everyone except the worthy laird was at first anything but cordial. However, the opposition began to die out as soon as the scheme proved self-supporting, and the obloquy of being a moss tenant wore off in a few years' time. By the end of 1774 there were in all thirteen settlers who disposed of 104 acres, and this was as much land as could be reclaimed with the available water supply.

The part of the ground first cleared was known as the Low Moss. It lay next the arable land, and the depth of peat was only 3 feet. It was quite accessible, and the clearing made such progress that by 1774, seven years after the first tenant started work, it had begun to yield good crops.

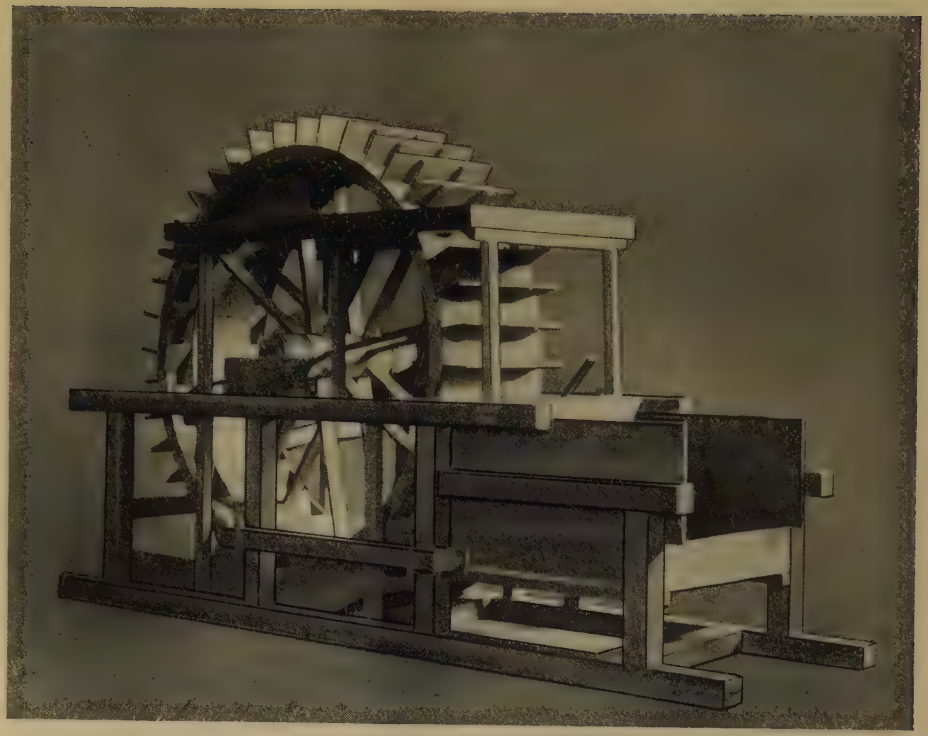
The more remote tract of the High Moss, which was from 6 to 12 feet in depth, had now to be tackled. To reach this deep bog it was necessary to cross from 300 to 400 yards of the Low Moss, and as the High Moss was so soft and treacherous that it was quite impassable for horses, the reclamation of it appeared almost impracticable unless a road were made across it, and even then the work must be one of much difficulty.

Without delay the proprietor had a road cut through it, 12 feet broad, by floating off the moss down to the clay, and along this the new tenants took up their holdings. In 1775 twelve settlers had taken up 8 acres each on the High Moss, but in consideration of the greater difficulty and less favourable conditions of the work no rent was to be payable for the first nineteen years of the lease. From the twentieth year onward the rent was the same as that of the other tenants. Every encouragement was given by the laird, and the success of the first twelve led to other settlers arriving every year, so that in 1782 there were twenty-nine of them at work, and with the previous thirteen on the Low Moss there were altogether forty-two busy with their families clearing 336 acres of the bog.

Lord Kames died in the end of 1782 in his eighty-seventh year, but he had the satisfaction of living to see the successful issue of his great scheme, and to know that his work so well begun would be carried on energetically by his successor.

Mr. George Home Drummond, who entered into possession in 1783, at once set about to subdue the rest of the moss, of which there was still an area of 1000 acres Scots (or 1200 imperial). The difficulty was the water supply, if more tenants were to be profitably employed and the work expedited. But it was also necessary to open up the ground better. A new road was therefore cut down through the moss to the clay, half a mile further in and parallel to the first lane. The new road and the prospect of a better stream of water brought more settlers in, and by 1785 fifty-five new tenants had arrived, who disposed of 440 acres more of the High Moss.

The available water had been all used up, and the laird set about to increase the supply by using the river Teith, which ran from a higher district, and could, with proper mechanical appliances for raising the water, be turned to good account. There were then almost no capable engineers in Scotland, and the art of casting large iron pipes and making economical steam engines was almost in its infancy. Mr. George Meikle of Alloa, a skilful millwright and son of the inventor of the threshing mill, offered his services, and produced a model of a large water wheel constructed by his father and himself for raising water on a new and very simple principle. The Teith was not high enough to be conveyed directly to the reclamation, but at a place now occupied by the Mill of Torr, 2½ miles above its confluence with the Forth, there was a sufficient fall to produce the necessary power. The plan was approved, and the Great Wheel was erected at that spot by Mr. Meikle in the spring of 1787, and its beneficent labours went on without intermission for fifty-two years, until 1839, when the work was completed and its services were no longer required.



MODEL OF THE GREAT WHEEL AT BLAIRDRUMMOND

By which the water was raised from the Teith to carry off the peat moss from 1787 till 1839.

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The wheel was 28 feet in diameter and 10 feet broad. Its peculiarity consisted in its having a double ring of buckets set inside the circumference of the float boards at each side, and so placed as to lift part of the water from the stream and discharge it as each bucket came up, and was gradually inverted as it reached the apex of the circle. The water thus discharged round the edges of the rim, which overhung the arms a short distance, was caught in a trough at each side and conveyed away in a large pipe made of wooden staves hooped with iron like a barrel.

The model is still to be seen in the museum at Blairdrummond, and, through the courtesy of Mr. Ballingall, I have been able to make the photograph of this interesting old piece of mechanism, from which the accompanying figure is taken. The principle is not new, as it is an adaptation of the ancient Persian and Chinese wheels, but it was new to Scotland, and I believe the independent invention of a clever man with nothing but his own originality to direct him.

By the Great Wheel the water was raised 17 feet and conveyed in wooden pipes made of staves hooped with iron, 18 inches in internal diameter, for a distance of 354 yards underground. It then rose to the surface and flowed along a raised aqueduct on the top of a bank 1400 yards in length, and from 8 to 10 feet above the level of the adjacent ground. The quantity of water thus supplied to the tenants more than a mile away was 40 hogsheads a minute, but had the pipes been wider than 18 inches inside, the wheel could have raised 50 per cent. more. The whole cost to the proprietor was about £1000, and before he began operations, in order to induce him to embark in the undertaking, the moss tenants offered, of their own accord, to pay the interest on any sum he might expend. But after it was completed he generously refused, as a reward for their industry, to allow them to do anything towards implementing their part of the bargain. This shows the kind and friendly feeling that subsisted between some lairds and their tenants in the brave days of old.

To obtain the best results, a canal had to be cut for a distance of nearly 3 miles through the centre of the moss, and sluices were made at intervals to admit water to the reservoirs of the different tenants. The wheel worked continuously day and night, and these reservoirs were used to store the water raised during the hours of darkness. The whole 24 hours' labour of the wheel was thus profitably employed, and by 1790 eighteen more tenants had taken up allotments on 144 acres of the High Moss.

All the area was now disposed of except the Flow Moss, 400 acres in extent and nearly 3 feet above the level of the surrounding moor. This was a semi-fluid quaking bog, so soft that a pole could be thrust with one hand to the very bottom. The reclamation of such a morass was considered almost impossible, and the general opinion was that the moss operations had now arrived at their *ne plus ultra*, and that the bog was destined to remain a nuisance for ages to come. But this was not the view of the sanguine laird, who was determined to complete his territorial conquest, and after many failures, he at last succeeded in bringing in a stream of water and carrying it across the centre of the bog. This was, however, not all. The further difficulty confronted him of inducing settlers to live on it and begin the reclamation. He finally bargained with some of the nearest tenants of the Low Moss to take leases of portions of the morass, and to encourage them he agreed to advance £12 by instalments to each until 1 acre had been cleared for which the tenant or his successor was bound to pay 12 shillings of yearly rent, or 5 per cent. on the sum advanced. As soon as the ground was cleared, the holding was to be disposed of to purchasers, who would, no doubt, be easily found.

The plan worked well, and, in 1791, thirty-five of the old tenants agreed on these terms to take up 8 acres each of the Flow Moss. When every tenant had cleared his acre, thirty-five additional tenants were to be secured, so that the moss would be inhabited by 150 families altogether. To further encourage the settlers on the High

Moss, it was determined to extend the period of their thirty-eight-year leases by nineteen years, to fifty-seven years in all. During the third nineteen years the rent was to be one guinea per acre, the value of the cleared land at the time, but much less than it was expected to (and did) become before the expiry of the lease.

Thus the settlement was completed, and 1200 Scots, or 1440 imperial acres, of what thirty years before had been a desolate bog, were converted into a thriving township with 150 families and a population of from 800 to 1000 industrious folk. At the Census of 1811 there was a population on the moss of 886, made up of 186 families, containing 423 males and 463 females, the female element having even then and there begun to predominate over the other sex.

The whole land cleared by the year 1817 was about 1130 acres, and the last of the leases in the Kirk Lane expired in 1855. But long before then the tenants were reaping the fruits of the proprietor's foresight and their predecessors' labour. So early as 1774 some of them began to dispose of their holdings, and between that date and 1792 no fewer than fifty sales took place, the whole sum realised for the sale of the leaseholds being £849. Soon afterwards the reversion of leases tripled in value, and many insignificant moss lairds blossomed out into large farmers in the vicinity.

After the success of the settlement was assured, a new turnpike road was formed along the north side of the moss, largely at the expense of the proprietor, to give the tenants a better access to the mills and markets. They voluntarily came forward and offered him a contribution of 100 guineas towards it, but, with the same generosity as had been shown on a former occasion when the prospects were less bright, he again declined to take anything from them, even when they had passed from the stage of poverty to one of comparative affluence.

The moss tenants did not send nearly all the peat into the Forth, as the lowest part of the moss, which made excellent fuel, was cast

and dried, and what they did not use at home was sold in Stirling and the surrounding villages in large quantities, the revenue from which was about £100 a year. In 1796, thirty years after the scheme had been planned, there were 764 inhabitants, with 54 horses and carts, 201 cows, and 102 good houses. These were built from bricks made on the ground by the tenants themselves at a cost of about £15 each. The land produced 32 bushels of oats per acre, and the value of the crop on the 400 acres that had been cleared up till that time was, at the current fiars price, about £2240.

The method of removing the moss, to clear the ground, was, as we have seen, to cut it into pieces and throw it into the channels that carried it away to the river. As the strip next the first channel was thus cleared off, a second channel parallel to it was cut in the clay close to the face of the moss. These conduits were about 2 feet deep and 2 feet wide, and a capable man could cut and throw in 48 cubic yards in a day for one shilling, or at the rate of one farthing a yard. The same quantity, if carted away, even at the very low rate of wages prevailing a century ago, would have cost 24 shillings. This outlay would have made the work quite impossible. The settlers worked with immense zeal and energy from dawn till dusk, and did not mind being often soaked to the skin. On a good day hundreds of men, women, and children might be seen labouring on the moss with the greatest assiduity. The women sometimes declared that they could make more on the moss than at the spinning wheel, and, indeed, they were often to be found working at night by the light of the moon.

Such a thing as an eight-hours' day and the ca' canny principle of the twentieth-century trade unionists, was not dreamt of among the unsophisticated dwellers in that old labour colony, and it was largely their energy and enthusiasm for work that made the settlement such a success.

But perhaps the most striking feature of the establishment was the kind of dwellings used by the original settlers on the High Moss,

The housing question is always the chief difficulty with the planning of small holdings, and the method of economically housing the old moss lairds is one that deserves to be mentioned here as on object lesson to all modern sanitary authorities and builders of cheap dwellings in garden cities. On the cleared areas good brick cottages were, in course of time, erected for the modest price of about £15 each, but not until the peat had been removed. These hardy Highlandmen, children of the mist, from the Braes of Balquhidder and Rob Roy's rainy country, were not accustomed to many luxuries. Their tastes were simple and their necessities of life few and easily satisfied. They wanted, each man of them, a self-contained mansion close to his work on his own estate, no matter how damp and humble, wherein to bring up a healthy family in the degree of independence and respectability prevailing in the colony.

The method of construction of the moss houses was as follows. A deep trench was first cut in the moss and carried down into the clay round the site selected for the dwelling. In the centre of this was left a large block of solid peat of the same size as the house. Then *the house itself was scooped out of this square block*, as a child hollows out the heart of a turnip to make a lantern. The walls were 4 feet thick at the base and 3 feet at the roof level which was perhaps at first 12 feet above the clay floor. The gables were completed with sod or mud, and the timber for the roof was given gratuitously by the proprietor. As the walls dried and contracted they sank down, perhaps to half the original height, so that a roof originally 10 feet high ended in coming down to five.

We read of the horrors of contracting chambers in the cruel middle ages, but here were contracting chambers, neither cruel nor horrible, in which people lived for many years in happiness and also —let modern sanitarians and public health officials take note—in the best of health. The antiseptic qualities of the peat, in spite of the dampness of the dwellings, prevented any serious disease. The people lived to great ages, and many of their grandchildren, still on

the ground, can look back over eighty or ninety years to the happy days of the old moss lairds.

The sites of these remarkable dug-out dwellings were too soft to carry a house on the top of the peat, as a stamp with the foot would make the whole moss quake for 50 yards around, and any house that might be put on it ran the risk of being shaken as by an earthquake. At other places on the Low Moss, however, the houses were set on a wooden floor, laid on the moss, and were built of moist peat and turf that dried and hardened in time. They were roofed with peat and heather, which began to grow vigorously, so that the whole settlement was dotted with picturesque huts, shaggy with purple heath and moorland plants, and fragrant with peat reek, and also, it should be mentioned, with the aroma of mountain dew at times, for which the King's Gaugers had a particularly keen scent when they visited the colony. The peat stacks were sometimes made hollow like the houses, and inside of the innocent-looking exterior there lurked the warm-hearted "Ewie wi' the crooked horn," whose discovery and extermination sometimes gave the laird and the minions of the law a lot of trouble.

The moss lairds were a community by themselves. Gaelic was their tongue and the philabeg their dress, and the old feeling of clanship was strong among them and their children. After they had begun to increase in numbers, their social and moral condition were attended to by the appointment, in 1793, of a schoolmaster, who could speak both Gaelic and English and also acted as minister to the community on Sunday. He was paid the handsome salary of £10 a year by the Society for Propagating Christian Knowledge. In order to obtain the services of a teacher of superior qualifications, the laird added £5 to this salary and provided gratis a school-house, a dwelling-house, a kailyard, fuel, the maintenance of a cow, and an acre of ground for a miniature glebe worth a guinea a year. With all this, however, the worthy preceptor was far behind Goldsmith's parson, who was reckoned as "passing rich on forty pounds a year."

Money, of course, had at that time about thrice the purchasing power it has in our day, a fact that must be kept in mind when making comparisons between present emoluments and those of the eighteenth century.

The success of this reclamation led to further work of the same sort on the neighbouring peat mosses. Mr. Drummond acquired 280 acres of the Poldar Moss below Thornhill. By the year 1844 he had cleared 170 acres of it at Littleward, between the Forth and the Goodie Burn, by means of water impounded in reservoirs on the higher part known as Flanders Moss. The moss was here very deep, and the whole of his portion was never reclaimed.

Another neighbouring laird, Col. Graham of Meiklewood, who owned 130 acres of the good Carse land along the Forth, immediately to the south of the Blairdrummond Moss, was animated by Mr. Drummond's success, and set to work to float off the part of the bog on his estate. He gave an account of his operations in the *Highland Society's Transactions* for 1832. He had not a supply of gravitation water at hand, but, being close to the Forth, he erected a 10 horse-power steam engine, which pumped up the water to a height of 38 feet above the river at the rate of 5 tons a minute. It was conveyed 400 yards in wooden pipes, and kept twenty-five men constantly at work. The gallant Colonel in his paper says he found it best to cut the levels or channels in pairs, working one squad of men against the other, so as to promote wholesome emulation as to which would do the greatest amount of work. At one period, one half of his men were Irish and the other half Scots. "When the strife of rivalry commenced, heroic deeds were achieved, and I thought my heroes were much better employed than others of more renown; for mine were making food for men, while they were making men food for worms."

He began operations in May, 1828, and by 1832 the whole 130 acres were cleared and bearing a crop. The moss was 10 feet deep, and the removal of so much in less than four years was

certainly a great achievement. The work cost him about £35 an acre in addition to the price of the engine, but it gave him great delight as well as a good return. "Notwithstanding all my disadvantages," he says (p. 227), "I shall have the land for less than half its value. It is true, the land was mine before, but then it never yielded a farthing of rent, and did a great deal of injury to the surrounding land by keeping it in a damp state. Besides, the existence of so ugly an object in the midst of my property was exceedingly disagreeable. However, ugly as it was, I wish I had a thousand acres more of it, and I should soon have enough cleared to pay the expense of the remainder."

These figures give some idea of the value of the cleared land in 1832, and the inducement there was to carry out schemes of reclamation at that time. If the £35 that the clearing cost was less than half the agricultural value, the ground must have been worth £70 an acre, and no wonder the adjoining moss lairds on Blairdrummond became prosperous people so soon. Land values have greatly declined since those good days for farmers, and now the best of that part of the Carse only fetches 35s. to £2 an acre of rent.

During the clearing of the moss many interesting relics of antiquity were found. The remains of an extensive forest of oak, alder, birch, hazel, and willow trees, whose roots were in the clay, had to be removed at great trouble to the tenants after the covering of peat was swept off. Many of these trees were of great size, larger than the average stems in recent forests. In an interesting paper by the Rev. Christopher Tait in the *Transactions of the Royal Society of Edinburgh* (Vol. III. 1793), we are told (at p. 272) that one of the oak trunks was 50 feet long and more than 3 feet in diameter. We are further informed that 314 circles were counted in one of the roots. Another stem was 4 feet 8 inches in diameter, and a third was found in 1823 16 feet in circumference. These immense trees had apparently been cut across at a height of about 3 feet from the ground, and allowed to lie where they fell. On some stems distinct traces of

axe marks were visible. An old road about 4 yards broad was also laid bare near Drip, under the eastern end of the moss. It was constructed on what is known in the colonies as the Corduroy system, with tree stems laid close together at places where the clay had been particularly soft. Ancient brass pots were discovered on Ochtertyre and Blairdrummond Mosses, all of which point to the Roman occupation about 81 A.D. At that time there must have been an ancient forest that had flourished for several centuries before the Roman invasion. The trees were felled to destroy the shelter they gave to the Caledonians, and not for the sake of timber, otherwise the valuable trunks would not have been left to rot on the ground. After the ground was thus encumbered with fallen trees, the forest did not spring up again, but became overgrown with peat. The moss, when the clearing first began in 1766, may thus have been some 1685 years old.

But there were also found relics of still older inhabitants of the Forth Valley under the moss. In 1824, the bones of a large whale were found, some of which are still to be seen in the museum at Blairdrummond. These bones were embedded in the clay a few feet down, and, as we have already noticed, were lying beside traces of human weapons of an earlier period.

We thus go back to a time, perhaps 3000 years ago, when the fair valley was a secluded arm of the ocean, where whales and other animals were hunted by primitive men, and fine mud was being laid down in the quiet water. Then the sea bed was slowly raised by a great upheaval of the land, and the salt water retired to a distance leaving bare a broad expanse of soft mud. On this Carse land a noble forest sprang up in time, and gigantic oaks and other native trees grew on it for 300 or 400 years or more, among which our savage ancestors made their homes and hid securely from their relentless foes. Agricola with his Roman legions appeared on the scene in the first century of our era, and proceeded to cut down the splendid forest out of wanton mischief and from the sheer lust of conquest.

Then, like a fox in a henhouse, he left the victims lying beheaded where they fell. A dense growth of peat covered up the fallen giants of the forest, and nothing more was seen of them for 1760 years until Lord Kames appeared and restored the Carse clay to the condition it was in after the sea bed had left it dry some 2400 or more years ago. Such in brief is the eventful tale of the appearance, clearance, and disappearance of the famous old Blairdrummond Moss.

But the Blairdrummond Moss was only the eastern part of the vast peat bog that covered the Carse land a century ago. The process of reclamation by floating off other portions was continued till about 1865, and I well remember seeing the shores of the estuary as far down as Bo'ness covered with lumps of peat when these later clearings were going on.

While this was, no doubt, an easy and expeditious way for the riparian proprietors to get quit of their waste products, it was not so convenient for some of their neighbours and for other people who had fishing interests lower down the river. Salmon fishing with stake nets and "cruives" was an important industry in the Forth, and the mass of floating moss and peat pulp was so great that it grew into a public nuisance, and both the fish and the traps for them as well as the oyster beds in the estuary, became choked with moss litter. To prevent the industry being thus damaged, the floating away of the mosses had to be prohibited, and for the last forty years no more reclamation of this kind has, I believe, been attempted, although there are still hundreds of acres of peat bogs in the Vale of Menteith.

This chapter is mainly a history of past achievement and of the triumph of mind over matter, but I wish to conclude the story and adorn the tale by pointing out the moral, or at least by making a new suggestion that, I hope, may commend itself to practical and patriotic minds.

PART OF THE OCHTERTYRE MOSS STILL UNRECLAIMED IN 1912

THE EASTER BRANCH OF THE WATER LEAD MADE BY LORD KAMES ALONG THE SOUTHERN EDGE OF OCHTERTYRE MOSS.

To face page 278.

The former chapters of this book have *inter alia* discussed such subjects as oil shales and land-reclamation schemes. To many oil shales and peat bogs may appear as far asunder as the poles, but this is only a superficial view of the matter. The problem before us is the acquisition of more good land by means of the sweeping off or denudation of its useless peaty covering. Denudation, as we have seen, has in previous geological ages often been useful to man in uncovering valuable mineral deposits that once lay buried under thousands of feet of rock, and the process may still be made useful at certain places in uncovering valuable food-producing land for the use of the community.

But it will not help matters if we destroy one industry in order to promote another, and thus the removal of the remaining peat by Lord Kames' method need not be further considered. The peat was considered by him a waste product to be got rid of and transported from the ground as cheaply as possible, no matter whether the fisheries were damaged or not. But waste materials need not always be swept into the sea. It has happened before that these have, in scientific hands been turned into by-products, and may have become, like the sulphate of ammonia in the oil works, some of the most important products of all.

Now it so happens that peat also contains ammonia as well as other valuable ingredients such as can be extracted from oil shale itself. The main difficulty in the case of peat is first to get rid of the enormous quantity of water that is contained in the raw material. Here lies the rock on which most peat industries have been wrecked, but it appears to me that under certain conditions this formidable obstacle may not be insurmountable.

In ordinary circumstances the distillation of peat is an industry by itself, which must stand or fall on its own merits. But here we have a new factor introduced, one that is well calculated to help out the solution of the problem.

Even if the suggested new peat industry on the Carse

were to prove unprofitable in itself, it would ultimately result in making bad land into good, and in providing permanent employment and producing good food for many honest folk where there is not a living soul just now, and only grouse and heather occupy the shaggy wilderness. No doubt the sporting value of the Flanders Moss and other tracts of local moorland is considerable, but grouse and rabbits can live quite comfortably on places where the subsoil is far less valuable or has no other value whatever. There are enormous tracts of Scottish land that are not worth reclaiming, and can never be advantageously used for anything but sport, but it is surely false economy and contrary to patriotic principles to let the idea of sport, which after all is a luxury for a few rich people, stand in the way of schemes of public utility in those limited areas where the land is well worth reclaiming and turning to the best advantage.

In order to test the quality of the Blairdrummond peat, Mr. Ballingall kindly had a sample of the Ochtertyre moss cut, and Mr. A. H. Crichton was good enough to have it analysed for me at the Philpstoun Oil Works of Messrs. James Ross & Coy.

The wet peat was found to contain 81 per cent. of moisture, so that only 19 per cent. was of economic value.

When the water was eliminated by drying, the general results were as follows :

Ash	7·80	per cent.
Fixed carbon	38·20	„
Volatile matter	54·00	„
	100·00	„

The volatile matter contained sufficient ammonia to produce 34 lbs. of sulphate per ton. This is not a large percentage certainly, but at the present price of £15 or so per ton each pound is worth a little more than 1½d. The value of 34 lbs. is thus 4s. 3d.

Now, if we compare the capabilities of wet peat with those of oil shale, we find that while in peat we have some 80 per cent. of

water to get rid of, in shale there is 70 to 75 per cent. of useless and heavy ash, and only from 30 to 25 per cent. of carbon and hydrocarbons are left from which the useful products are obtained.

When peat is dried in the air, about 70 to 75 per cent. of the water can be removed, but to get rid of this quantity requires dry weather and more sunshine than is always found in the Vale of Menteith. A considerable part of the moisture will thus always have to be eliminated by artificial means.

A reference to Chapter XI. will show that it is necessary to blow "soft" steam in considerable quantity into the retorts to promote the distillation and production of ammonia. This must be introduced near the bottom of the retort at the place where the temperature is high enough to dissociate the water vapour and separate it into its component elements. The steam thus used at the oil shale works is derived from the exhaust of the engines, chiefly needed in connection with the mines and crushers. In peat oilworks, where there would be no mines or crushers, very little engine power would be required, and little or no waste steam would be produced, as a few small gas or oil engines might do all the necessary mechanical work. The steam that would be required in larger quantities might well be obtained from the peat itself, whose remaining water might be eliminated by heat derived from the coke and residual gas and conveyed to the retorts from the drying chambers.

Little or no coal is now used in distilling Scottish oil shale, as the heat from the combustion of the residual gas is usually sufficient to keep up the temperature of the retorts. In the same way, no foreign fuel would be needed to distil the peat, and with proper mechanical appliances the amount of labour needed inside the works would be comparatively small. Most of the manual work would be required outside, in cutting and preparing the peat for treatment and reclaiming the land.

The point need not be elaborated further, as it is one for experts to deal with. I am well aware the peat distillation in Ireland and

elsewhere has hitherto been unsuccessful, but the distillation of oil shale might prove a failure at these places also for want of the men with the Scottish knack of knowing how to do it, and the ability to overcome difficulties as they arose. But in any case, and to sum up the argument, the following points are, I think, worth careful consideration and investigation :

1. Oil-shale distillation in Scotland is now a profitable industry, and is likely to become more so, especially if oil is to be largely used in the future as a fuel instead of coal on land and sea.

2. Oil shale contains 70 to 75 per cent. of useless ash that costs something to get rid of, and the refuse heaps cover up much good ground.

3. Shale has to be mined, and it pays to raise it from depths sometimes of over 1600 feet.

4. Shale cannot be profitably distilled without the addition of water in the shape of steam admitted into the retorts.

5. Peat contains 70 to 80 per cent. of water and only 8 per cent. of ash, and more than half of the water can easily be removed by drying in the air.

6. Peat does not require troublesome and costly mining, but only digging from the surface, with little danger or expense.

7. Peat contains in itself the water that has to be added to the dry shale to enable it to be profitably distilled.

8. The peat in the Vale of Menteith, when dried, contains three times as much carbon and hydrocarbons as oil shale, and these include, in greater or smaller quantities, coke, oil, paraffin wax, motor spirit, and gas, as well as ammonia.

9. This peat when removed will not leave dangerous cavities under the ground, or huge mounds of rubbish to destroy the surface, but will produce a tract of fertile land that can grow valuable crops and support a new and thriving community for all time.

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These points afford, I venture to think, food for profitable reflection. If this suggestion for the further reclamation of the Forth peat bogs, and the proposals made in a former chapter relating to the foreshores, should lead to the improvement of the natural resources of the valley and the better employment of its busy inhabitants, then I shall consider that my trouble in this somewhat laborious investigation has been attended with a full reward.

NOTE.—The accompanying map, showing the progress of the reclamation up till 1813 on Blairdrummond Estate, has been compiled chiefly from that accompanying the article referred to in the *Farmer's Magazine* for 1817. It has been corrected topographically from the 6 inch Ordnance Survey Map, and reduced to a scale of 3 inches to a mile. The various roads across the moss are shown with the 10 acre crofts and cottages on either side. The longest of these, the Kirk Lane, is the one that was cut through the deepest part of the morass after the shallower portions to the east had been partly cleared by the first settlers.

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